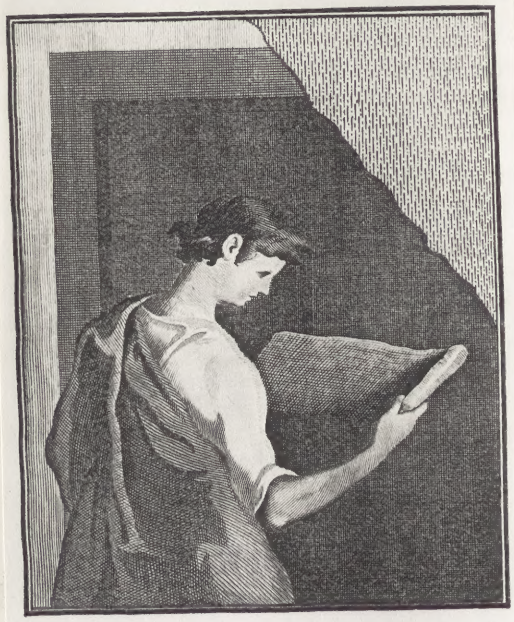
ICOM COMMITTEE FOR CONSERVATION

7th Triennial Meeting Copenhagen 10-14 September 1984

Preprints

COMITÉ DE L'ICOM POUR LA CONSERVATION



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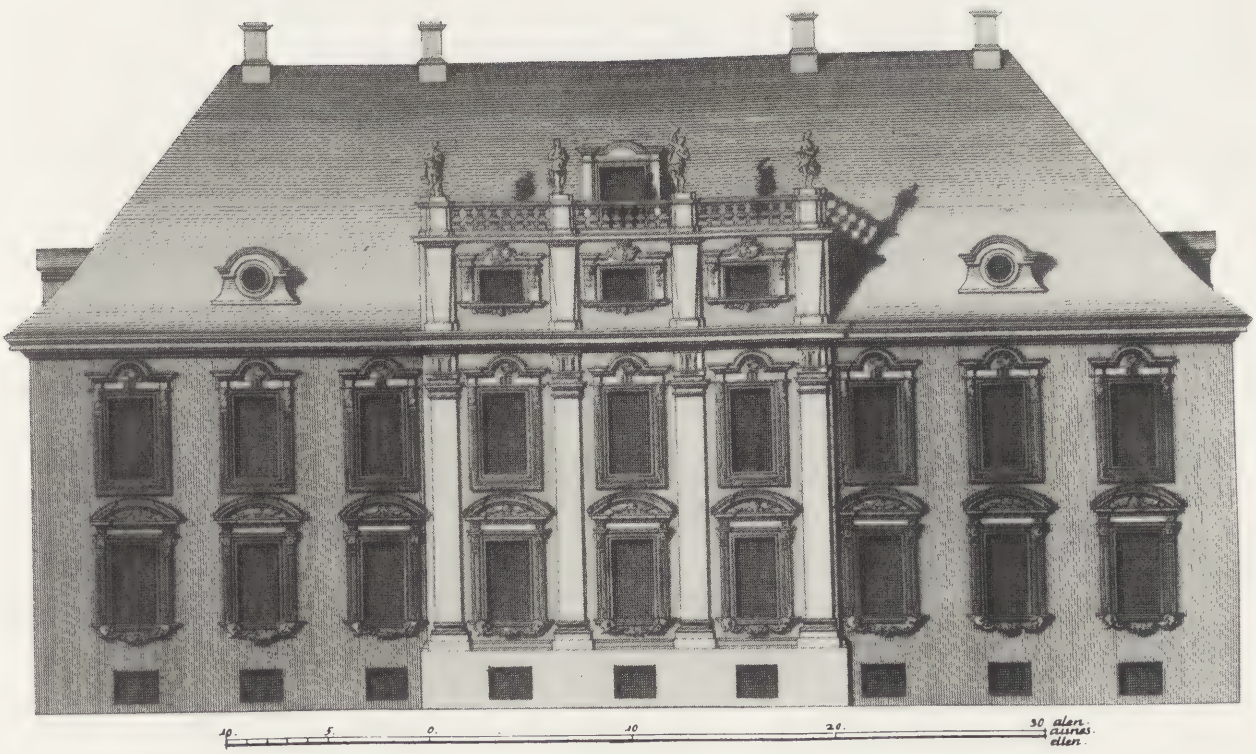

The *Moltkes Palæ,* Copenhagen, engraving from *Hafnia hodierna* by L. de Turah, published 1748

The International Council of Museums in association with the J. Paul Getty Trust

Published by the International Council of Museums, Paris, 1984
in association with the J. Paul Getty Trust

Editor: Diana de Froment

Acknowledgements:

The ICOM Committee for Conservation gratefully acknowledges the support of ICCROM towards the publication of the Preprints.

The ICOM Committee for Conservation also acknowledges with thanks the following Danish authorities and foundations for their support of 7th Triennial Meeting in Copenhagen:

The Ministry of Cultural Affairs/Ministère des affaires Culturelles

Danish Research Council for the Humanities/Conseil Danois des Recherches Humanistes

Augustinus Fonden

Carlsbergs Mindelegat for Brygger I. C. Jacobsen

Danmarks Nationalbanks Jubilaeumsfond af 1968

DLH-fonden

Dronning Margrethe og Prins Henriks Fond

Kong Frederick og Dronning Ingrids Fond til humanitaere og kulturelle formaal

Knud Højgaards Fond

Kreditforeningen Danmarks Fond for saerlige Formaal

Lillian og P.T. Nielsens Fond

Printed in England by Reedprint Ltd., Windsor

Available from:

The International Council of Museums
1 rue Miollis
75732 Paris
France

and

The International Centre for Conservation
13 via di San Michele
00153 Rome
Italy

Participants in the meetings of the ICOM Committee for Conservation are personally invited not as representatives of their country or institution but as specialists in their field.

Les participants aux réunions du Comité pour la Conservation de l'ICOM sont invités personnellement à titre de spécialistes; ils ne représentent ni leur pays ni leur institution.

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The J. Paul Getty Trust is pleased to co-publish the Preprints for this Seventh Triennial Meeting in Copenhagen of the ICOM Committee for Conservation. Since it was first established in 1951, this Committee has been dedicated to promoting a multidisciplinary approach to conservation, by providing a forum for exchange between the conservator, scientist and curator. The J. Paul Getty Conservation Institute, one of the Trust's operating activities, is based upon the importance of this integration of disciplines which underlies its three programs of applied research, advanced training and information. The Getty is pleased to collaborate with ICOM in making these Preprints available.

La Fondation J. Paul Getty a l'honneur de coéditer les prétirages de cette septième assemblée triennale du Comité de l'ICOM pour la conservation, tenue à Copenhague. Depuis sa fondation en 1951, le Comité s'emploie à promouvoir une conception multidisciplinaire de la conservation, en offrant au restaurateur, au chercheur et au conservateur une tribune pour communiquer entre eux. L'Institut de conservation J. Paul Getty, l'un des organes opérationnels de la Fondation, est basé sur l'importance de cette intégration de disciplines qui sous-tend ses trois programmes: recherche appliquée, formation avancée et information. La Fondation Getty est heureuse de collaborer avec l'ICOM pour diffuser ces prétirages.

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Composition and working rules

1. The Committee and its aims

1.1 *The ICOM Committee for Conservation* is a permanent committee of the International Council of Museums.

Among its aims are:

a. The achievement and maintenance of the highest standards of conservation and examination of historic works by bringing together from all countries those who are responsible for cultural property: restorers, research workers and curators.

b. to promote researches of a scientific or technological nature pertaining thereto.

c. to collect data and information about materials and workshop methods.

d. to make generally available by publication or otherwise the results of such enquiries.

1.2 The ICOM Committee for Conservation is composed of the Directory Board, Working Groups with their Coordinators, members of ICOM in good standing who have selected the Conservation Committee as the sole International Committee on which to vote in accordance with Article 31 of ICOM statutes, and coopted members, as provided in Articles 11 and 15 of the Rules and Procedures for the International Specialized Bodies of ICOM. The members of the Directory Board and the Coordinators must be members of ICOM or must undertake to become members within three months of appointment.

2. Directory Board

2.1 The Directory Board (hereinafter called the Board) is composed of eight members elected for three years by the Committee and one ex-officio member, namely the Director of the Rome Centre. Members are eligible for reelection.

2.2 The Board elects its Chairman from among the elected members and appoints an Administrative Secretary and a Secretary for Publications.

2.3 Among the elected members of the Board, who may also be Coordinators, should be represented Museum Curators, Restorers and Museum Scientists.

2.4 Delegates from international organizations such as UNESCO, IIC, and ICOMOS will normally be invited to attend meetings of the Board as observers.

2.5 The Board will endeavour to meet at least once every year.

2.6 The functions of the Board are the following:

a. to appoint Coordinators for definite tasks and for fixed periods of time.

b. to establish with Coordinators the programme of the Committee for Conservation.

c. to control the progress of work.

3. Coordinators

3.1 Coordinators will hold their offices at the discretion of the Board.

3.2 The Coordinator will choose the members of his Working Group in consultation with and with the approval of the Board and will direct its activities.

3.3 With the approval of the Board the Coordinator may organize joint meetings of specialists in his field, visits to laboratories, sites etc., having a direct bearing on the progress of his investigation.

3.4 Each Coordinator will submit, annually, to the Secretariat of the Committee for Conservation and not later than three weeks before the meeting of the Board, a report on the progress of the work of his group.

4. Working Group Members

4.1 On a proposal from the Coordinator, and with the approval of the Board, members will be assimilated in a group and be allocated a particular subject to study.

Statuts

1. Le comité et ses buts

1.1 *Le Comité de l'ICOM pour la Conservation* est un comité permanent du Conseil International des Musées.
Ses buts sont entre autres:

a. d'atteindre et de maintenir le plus haut niveau de la conservation et de l'examen des oeuvres d'art en mettant en contact ceux qui - dans tous les pays - sont responsables pour les biens culturels: restaurateurs, chercheurs scientifiques et conservateurs.

b. de promouvoir des études scientifiques ou technologiques relatives à cet objectif.

c. de réunir des données et des informations sur les matériaux et les méthodes d'atelier.

d. de diffuser les résultats de telles enquêtes par des publications ou autrement.

1.2 Le Comité de l'ICOM pour la conservation est composé d'un Conseil de Direction, de groupes de travail avec leurs coordinateurs, de membres de l'ICOM dont la situation est en régle et qui ont choisi le Comité pour la conservation comme seul Comité International dans lequel ils ont le droit de vote suivant l'article 31 des Statuts de l'ICOM ainsi que de membres cooptés comme le prévoient les articles 11 et 15 du Réglement des Organes internationaux spécialisés. Les membres du Conseil de Direction et les Coordinateurs doivent être membres de l'ICOM ou le devenir dans les trois mois qui suivent leur nomination.

2. Le Conseil de Direction

2.1 Le Conseil de Direction (appelé le Conseil ci-dessous) est composé de huit membres élus pour trois ans par le Comité et du Directeur du Centre de Rome, qui en fait partie ex officio. Les membres peuvent être réélus.

2.2 Le Conseil choisit son Président parmi les membres élus et nomme un Secrétaire Administratif et un Secrétaire aux Publications.

2.3 Parmi les membres élus du Conseil, qui peuvent être également des Coordinateurs, les conservateurs de musée, les restaurateurs et les spécialistes de laboratoire de musée doivent être représentés.

2.4 Des représentants des organisations internationales comme l'UNESCO, l'IIC et l'ICOMOS seront généralement invités à assister aux réunions du conseil à titre d'observateur.

2.5 Le Conseil essayera de se réunir au moins une fois par an.

2.6 Les fonctions du Conseil sont les suivantes:

a. de nommer les coordinateurs pour des tâches bien déterminées et pour des périodes fixées.

b. d'établir le programme du Comité pour la Conservation en accord avec les Coordinateurs.

c. de contrôler le progrès des travaux.

3. Coordinateurs

3.1 Les Coordinateurs garderont leurs fonctions sous l'approbation du Conseil.

3.2 Le Coordinateur choisit les membres de son Groupe de Travail en consultation et avec l'approbation du Conseil et en dirige les activités.

3.3 Le Coordinateur peut organiser avec l'agrément du Conseil des réunions de specialistes dans la matière de son ressort, des visites aux laboratoires, sites, etc. directement liées au progrès de son travail.

3.4 Chaque année et trois semaines avant la réunion du Conseil au plus tard le Coordinateur envoie au Secrétariat du Comité pour la Conservation un rapport sur l'état d'avancement du travail de son groupe.

4. Les membres des Groupes de Travail

4.1 Sur la proposition du Coordinateur et avec l'approbation du Conseil, des membres seront assimilés dans un groupe pour l'étude d'un sujet déterminé.

5. Procedure and Finance

5.1 The Committee for Conservation meets normally every three years in full session to hear reports on the progress of the work being carried out by the Working Groups under their Coordinator, to propose future programmes to the Board, and to encourage contact between the members of the Working Groups.
All interested persons may attend meetings with the approval of the Chairman of the Board.

5.2 While Groups meet by arrangement at times found to be most expedient, the Board will endeavour to meet annually.

5.3 Manuscripts prepared by Working Groups which are ready for publication shall be passed to the Secretary for Publications for submission to the International Coordination Committee for Publications.

5.4 The Committee's budget will be submitted for approval every three years to the full session of the Committee.

6. Amendments

The Board will have the power to make provisional changes in the composition and working rules to be presented for ratification at the next meeting of the Committee.

5. Fonctionnement et Finances

5.1 Le Comité pour la Conservation se réunit normalement tous les trois ans en séance plénière pour entendre les rapports sur l'avancement des travaux exécutés par les Groupes de Travail sous la direction du Coordinateur, afin de proposer les programmes futurs au Conseil et d'encourager les contacts entre les membres des Groupes de Travail.
Toutes les personnes intéressées peuvent assister aux réunions du Comité avec la permission du Président du Conseil.

5.2 Les Groupes de Travail arrangent des réunions aux moments les plus propices; le Conseil tâchera de se réunir chaque année.

5.3 Les manuscrits préparés par les Groupes de Travail destinés à être publiés seront envoyés au Secrétaire aux Publications afin d'être soumis au Comité International de Coordination pour les Publications.

5.4 Tous les trois ans le budget du Comité est soumis à l'approbation du Comité en séance plenière.

6. Amendements

Le Conseil peut faire des changements provisoires dans les Statuts à presenter pour une ratification à la prochaine réunion du comité.

By-laws for the Election of the Directory Board

1. The election of the Directory Board by the Committee takes place every three years during the Plenary Meeting of the Committee.

2. The Directory Board is elected by those members of the Committee who are present at the Plenary Meeting.

3. All electors are eligible.

4. Members can put themselves up for election by informing the Secretariat either orally or in writing of their candidacy not later than 24 hours before the election. No candidates can be accepted after this dead-line. Candidates should mention to the Secretariat whether they consider themselves a curator, restorer or scientist.

5. It is not necessary for a candidate to support his candidacy with signatures of members. A provisional list of candidates containing at least sixteen names in alphabetical order is prepared by the Directory Board.

6. The Secretariat prepares a voting-ballot by arranging the candidates in three columns according to their belonging to one of the three categories: curators, restorers or scientists. Each candidate can only appear in one column. Initials and full name of the candidate should be mentioned on the voting-ballot.

7. Prior to the election the Secretariat shall distribute one voting-ballot only to each individual member. The Secretariat shall keep a record of this distribution.

8. Prior to the election a Supervisor of the election is appointed from among the members present as well as two Overseers. The Supervisor opens the voting-boxes and reads the results. These are recorded by two persons appointed by the Secretariat. The Overseers check that the votes are correctly recorded.

9. Each member shall name a maximum of eight and a minimum of six candidates on the voting-ballot by placing a cross behind their names. Each column, corresponding with a category of curators, restorers or scientists should contain at least two crosses. Voting-ballots containing more than eight and less than six crosses are void.

10 Members shall put their individual voting-ballot into a previously sealed voting-box. Voting-ballots should be signed by the Supervisor before being put into the voting-box.
Voting-ballots not carrying the signature or initials of the Supervisor are void.

11. When the time allotted for the voting is expired the voting-boxes shall be assembled and opened by the Supervisor whereupon the public counting of the votes shall proceed.

12. The number of crosses appearing after the names of a candidate is recorded. When all voting-ballots have thus been counted the numbers are added up.

13. First elected are the two candidates in each column who have acquired the greatest number of votes. When two candidates in one category have obtained an equal number of votes and this number is greater than that of any other candidate in that category, they shall both be elected. When three or more candidates in one category have the same number of votes and this number is greater than that of any other candidate in that category two of them shall be assigned by lot. When two or more candidates in one category have acquired an equal number of votes and this number is smaller than that obtained by one other candidate in that category but greater than that acquired by any other candidate in that category one of these candidates shall be assigned by lot.

14. When thus the first six members of the Directory Board have been elected two further members shall be elected from among the remaining candidates, i.e. the two remaining candidates from any category having acquired the greatest number of votes. When two of the remaining candidates have obtained the same number of votes greater than that of any other remaining candidate they shall both be elected. When three or more of the remaining candidates have obtained the same number of votes and this number is greater than that of the other remaining candidates two of them shall be assigned by lot. When the above situations do not occur and two or more remaining candidates have acquired the same number of votes and this number is smaller than that obtained by one other remaining candidate but greater than that obtained by all other remaining candidates, one of them shall be assigned by lot.

Règlement pour les élections du Conseil de direction

1. L'élection du Bureau directeur par le Comité prend place chaque trois ans durant la Réunion plénière du Comité.

2. Le Conseil de Direction est élu par les membres du Comité présents à la Réunion pleniére.

3. Tous les électeurs sont éligibles.

4. Les membres peuvent se présenter eux-mêmes aux élections en informant le Secrétariat, soit oralement soit par écrit, de leur candidature pas plus tard que 24 h avant l'élection. Aucun candidat ne peut être accepté après cette date limite.Les candidats mentionneront au Secrétariat qu'ils sont conservateur, restaurateur ou chercheur.

5. Il n'est pas nécessaire pour un candidat de faire appuyer sa candidature par des signatures de membres. Une liste provisoire des candidats comprenant au moins seize noms dans l'ordre alphabétique est préparée par le Comité directeur.

6. Le Secrétariat prépare les bulletins de vote en répartissant les candidats en trois colonnes suivant qu'ils appartiennent à l'une des trois catégories: conservateur, restaurateur ou chercheur. Chaque candidat ne peut apparaître que dans une seule colonne. Les initiales et le nom entier du candidat seront mentionnés sur le bulletin de vote.

7. Avant l'élection le Secrétariat distribuera un bulletin de vote à chaque membre individuel. Le Secrétariat tiendra un registre de cette distribution.

8. Avant l'élection un Président de l'élection est nommé par les membres présents ainsi que deux Assistants. Le Président ouvre les urnes et lit les résultats. Ils sont enregistrés par deux personnes nommées par le Secrétariat. Les Assistants controlent que les votes sont correctement enregistrés.

9. Chaque membre pourra nommer au maximum de huit et un minimum de six candidats sur le bulletin de vote en plaçant une croix derrière leurs noms. Chaque colonne correspondant à une catégorie de conservateur, restaurateurs ou chercheur contiendra pour le moins deux croix. Les bulletins contenant plus de huit et moins de six croix sont nuls.

10. Les membres devront mettre leur bulletin de vote individuel dans une urne scellée auparavant. Les bulletins de vote seront signés par le Président avant d'être mis dans l'urne.
Les bulletins de vote ne portant pas la signature ou les initiales du Président sont nuls.

11. Le temps alloué au vote terminé, les urnes seront rassemblées et ouvertes par le Président; ensuite les votes seront comptés en public.

12. Le nombre des croix apparaissant après le nom d'un candidat est enregistré. Quand tous les bulletins de vote ont été comptés, les nombres sont additionnés.

13. Sont élus en premier les deux candidats qui, dans chaque colonne, ont acquis le plus grand nombre de votes. Quand deux candidats d'une même catégorie ont obtenu un nombre égal de votes et ce nombre est plus grand que celui de quelque autre candidat dans cette catégorie, ils seront considérés comme élus ensemble. Quand trois candidats ou plus dans une même catégorie ont le même nombre de votes et que ce nombre est plus grand que celui de quelque autre candidat dans cette catégorie, deux d'entre eux seront tirés au sort. Quand deux ou plusieurs candidats dans une même catégorie ont acquis un nombre égal de votes et que ce nombre est plus petit que celui obtenu par un autre candidat dans cette catégorie, mais plus grand que celui acquis par un autre candidat dans cette catégorie, un de ces candidats sera tiré au sort.

14. Ainsi quand les six premiers membres du Comité directeur ont été élus deux autres membres seront élus parmi les candidats restants, c.à.d. les deux candidats restants de quelque catégorie ayant acquis le plus grand nombre de votes. Quand deux des candidats restants ont obtenu le même nombre de votes plus grand que celui d'un autre candidat restant, ils seront élus. Quand trois ou plus des candidats restants ont obtenu le même nombre de votes et que ce nombre est plus grand que celui des autres candidats restants, deux d'entre eux seront tirés au sort. Quand les deux situations mentionnées ci-dessus ne se produisent pas et deux ou plus des candidats restants ont obtenu le même nombre de votes et que ce nombre est plus petit que celui obtenu par un autre candidat

Assigning by lot is carried out by the Supervisor according to a procedure of his choice. When more than two candidates from the same country are elected only the two candidates having acquired the greatest number of votes or being assigned by the above described procedure are confirmed. The vacancy thus created shall be filled by applying the procedure described in articles 13 and 14.

15. The newly elected Directory Board assumes its functions from the moment that the results are read to the Plenary Meeting by the Supervisor or the Secretariat.

16. The Supervisor shall decide in matters arising during the electorial procedure for which these By-Laws do not provide.

17. Immediately after the election of the Board, a Chairman and Vice-chairman will be elected. To this purpose the previous Secretary will provide appropriate ballots and conduct the election. The person acquiring the largest number of votes will be elected Chairman and the person receiving the next largest number will be Vice-chairman. In case of a tie for either office a second round of voting will take place between the candidates who have tied.
In accordance with article 13 of the Rules of procedure for the International specialized bodies of ICOM no Chairman or member of the Board may remain in office for a period exceeding six consecutive years.

18. As soon as possible, following the election of the Chairman and Vice-chairman, the Secretary of the Committee shall be appointed by the Board.

restant mais plus grand que celui obtenu par tous les autres candidats restants, un d'entre eux sera tiré au sort. Le tirage au sort est mis à exécution par le Président suivant une procédure de son choix. Si plus de deux candidats sont élus d'un seul pays, seuls les deux candidats ayant obtenu le plus grand nombre de votes ou étant assignés par la procédure décrite ci-dessus seront confirmés. Le vide créé ainsi sera rempli par l'application des articles 13 et 14.

15. Les nouveaux élus de Comité directeur assument leurs fonctions à partir du moment où les resultats sont lus à la Réunion plénière par le Président ou le Secrétariat.

16. Le Président décidera en la matière survenant durant la procédure électorale pour laquelle ces lois n'auraient rien prévu.

17. Immédiatement après l'élection du conseil de direction un président et un vice-président seront élus. A cette fin l'ancien secrétaire qui est responsable de tout ce qui se rattache à l'élection, distribuera des bulletins de vote appropriés. La personne ayant reçu le plus grand nombre de votes sera élu président et la personne suivante sera vice-président. Dans le cas d'un même nombre de votes pour ces deux fonctions il y aura un second tour scrution entre les candidats ayant reçu le même nombre de votes.
Conformément à l'article 13 du Règlement des organes internationaux spécialisés de l'ICOM le Président et les membres du Conseil de direction ne peuvent rester en fonction plus de six ans de suite.

18. Le plus tôt possible après l'élection du président et du vice-président, le conseil désignera le nouveau secrétaire du Comité.

Section 1

New Applications of Methods of Examination

Nouvelles applications de méthodes d’examen

COORDINATION DU GROUPE DE TRAVAIL "NOUVELLES APPLICATIONS DE METHODES D'EXAMEN"
BILAN ET PERSPECTIVES

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La crise, ou le changement qui touche aujourd'hui le monde des musées comme tous les secteurs de la vie économique et culturelle fait logiquement du patrimoine la plus précieuse des valeurs refuge. Rarement, sans doute, la notion n'a été plus étroitement liée à l'idée de sauvegarde, de défense. Et ce qu'évoque d'abord, aujourd'hui, celle plus paisible de conservation, c'est la même urgence de sauvetage. Cette prise de conscience a depuis longtemps dépassé le cadre national des institutions ou des laboratoires spécialisés : elle est maintenant universelle et mobilise, avec les plus hautes instances internationales, des associations telles que l'ICOM.

L'application des nouvelles méthodes d'examen est animée du même mouvement. Elle aussi s'est accélérée, en quelques années, avec la conviction nouvelle que les méthodes analytiques non-destructives issues des sciences exactes dans leurs développements les plus avancés peuvent, doivent être mises en même temps au service de la conservation. D'où l'appui croissant que se prêtent, dans l'étude des oeuvres, physiciens et historiens d'art, conservateurs et ingénieurs : les préoccupations de chacun se fondent, aujourd'hui, dans la certitude commune que le temps presse. De là aussi, sans doute, l'extrême variété, la richesse des méthodes mises à l'épreuve, et la rapidité de leur irruption dans le monde des musées : rarement on avait vu, semble-t-il, autant de cloisons s'abattre ensemble.

Appliquées au patrimoine muséal, les méthodes scientifiques se diversifient de jour en jour. A elle seule, la capacité des mini-ordinateurs a bouleversé les techniques d'examen et d'analyse et a permis de créer de vastes fichiers à caractère scientifique (banques de données spectrales...) ou muséologique. L'ordinateur contribue à affiner l'exploitation des résultats expérimentaux (déconvolution de spectres, réduction du bruit de fond, ...) et à simplifier, par exemple, les données multiples d'une étude par des traitements statistiques qui en extraient les paramètres. La compilation informatique des résultats physico-chimiques et muséologiques, puis des images sur vidéodisque va rendre possible, enfin, la mise en place d'un réseau mondial d'informations.

Les communications présentées reflètent quelques uns de ces bouleversements. Mais l'usage d'équipements lourds (scanner, tomographe, microsonde ionique ou accélérateur de particules) à des fins muséologiques va devenir courant et, vite, obligatoire. Notre groupe de travail traduit déjà cette dynamique internationale : il regroupe des chercheurs européens, américains et asiatiques conservant intacts leur mode de pensée et leur sensibilité individuelle dans l'approche commune du patrimoine par les méthodes scientifiques.
Le nombre élevé de ces contributions nous a conduit à les présenter en deux demi-journées.

1ère SESSION : NOUVELLES APPLICATIONS TECHNOLOGIQUES

Elle comporte huit communications sur l'étude scientifique des peintures par des techniques physiques non-destructives d'examen et d'analyse. Ces conférences associent généralement les activités de laboratoire aux travaux de restauration et aux études d'histoire de l'art.

Application aux peintures

Madame Perier d'Ieteren, Professeur d'Histoire de l'Art, a bien voulu animer la première partie de cette session.

C. PERIER D'IETEREN
(Belgique : Bruxelles, Université)

La contribution traite du dessin préparatoire des peintures de Gérard David. Dirigée par C. Perier d'Ieteren, l'étude a été menée conjointement avec M. Ainsworth (Metropolitan Museum of Art), N. Raynaud et L. Faillant-Dumas (Louvre). Les documents scientifiques (réflectogrammes infrarouges et radiographies) permettent de retrouver la technique et les outils employés par le peintre (plume, pierre noire, poncif) (1).

G. EMILE MALE, N. DELSAUX
(France : Paris, Louvre)

Exemple de collaboration scientifique entre service de restauration et laboratoire à l'occasion du travail délicat mené sur la "Charité" d'Andrea del Sarto. La confrontation de textes anciens et de la chimie des années 1750 a permis d'émettre une hypothèse sur la méthode de transposition de Robert Picault.

N.I. GRUZDEVA, N.G. GERASSIMOVA
(U.R.S.S. : Léningrad, Hermitage)

Le contrôle d'évolution de la couleur (coordonnées trichromiques et luminance) de témoins pigmentés imprégnés de métacrylate de polybutyl ou désinfectés au bromure de methyl est simplifié par l'emploi du colorimètre Vavilov qui opère sur une plage de un millimètre, à 15 centimètres de l'oeuvre.

L. FAILLANT-DUMAS
(France : Paris, Louvre)

L'étude menée en 1983 sur les oeuvres de Raphaël apporte des précisions sur sa technique picturale : exécution libre du dessin préparatoire au charbon ou au pinceau mais aussi usage de poncifs. La préparation à la colle animale est couverte d'un film d'huile de lin sur lequel repose l'impression ou ébauche au blanc de plomb diversement colorée.

M. del GARRIDO PEREZ
(Espagne : Madrid, Prado)

L'expérience acquise par le service scientifique du Prado dans la réalisation de radiographies grand format pour l'étude rapide in-situ des peintures sera illustrée par les oeuvres de Goya qui décoraient la "Quinta del Sordo", résidence du peintre à Madrid.

A. GALLONE GALASSI, F.G. ALBERGONI, B. BASSO, L.M. RECALCATI
(Italie : Milan, Ecole Polytechnique)

L'étude de quarante panneaux peints conservés à la pinacothèque de Brera révèle, au moyen de quatre méthodes physiques, des différences dans l'usage des techniques picturales traditionnelles employées par neuf artistes des Marches au XVème siècle : impression ou non de blanc de plomb sur la préparation, emploi d'outremer, d'azurite et même de lapis lazuli dans le manteau de la Vierge, etc...

I.N. HILGENDORF
(U.R.S.S. : Tbilissi, musée d'Art de l'état de Georgie)

L'application de la fluorescence ultraviolette, de la photographie infrarouge et de l'émissiographie par tube X pulsé de 200 kV a permis de retrouver l'image sous-jacente d'une peinture murale surpeinte du temple du monastère Udabno et d'estimer son graphisme antérieur au Xème siècle.

P. KLEIN
(Allemagne : Hambourg, Université)

Application de la dendrochronologie à la datation des panneaux de chêne peints. Le Professeur Klein expose les résultats de l'étude qu'il a menée récemment sur 5 tableaux attribués à Jean Fouquet (1415/20, 1477/81) : "Estienne Chevalier et la Vierge à l'Enfant" (> 1456), "Guillaume Jouvenel des Ursins" (> 1465), "Jester Gonelle" (> 1436), et signale les limites de la méthode.

Applications aux coupes de peinture

Trois communications ont trait à l'analyse des constituants de la couche picturale à partir de prélèvements microscopiques préparés sous forme de coupes transversales.

J.R.J. VAN ASPEREN DE BOER
(Hollande : Groningen, Université)

Point sur la préparation et l'étude optique et chimique des couches stratigraphiques : l'emploi de violet de methyl, noir B du Soudan, n-butylamine permet la caractérisation des liants à l'huile alors que celui d'iodéosine, Ponceau S, noir amide et fuschine ainsi que le chauffage de coupes minces permet la caractérisation des protéines ou des mélanges huile-protéines.

A.I. KOSSOLAPOV, A.V. SIZOV
(U.R.S.S. : Léningrad, Hermitage)
M. ENGELMAN, M. NENS, Ch. LAHANIER
(France : Paris, C.E.A., Louvre)

Deux études portent sur l'évolution de la composition du blanc de plomb, l'une réalisée par microsonde laser, l'autre par microsonde nucléaire PIXE (faisceau de protons de quelques microns). La préparation industrielle du blanc de plomb à partir du XIXe siècle réduit la teneur en argent d'un facteur 100 et augmente celle du zinc (de l'ordre du p.cent). Les autres impuretés étant liées à l'origine du minerai (2) peuvent également servir à l'authentification des peintures.

Applications aux documents graphiques

Deux études de documents graphiques témoignent de l'intérêt de l'excitation par faisceau de particules chargées pour l'analyse non-destructive de la matière y compris les composés organiques.

R.N. SCHWAB
(U.S.A. : Davis, Université)

Un faisceau de protons de 4,5 MeV accélérés par cyclotron a permis d'analyser ponctuellement ($\varnothing < 1$ mm) la composition de l'encre (Cu/Pb) des caractères de plusieurs centaines de pages de la bible de Gutemberg conservée à la "Edward Laurence Doheny Memorial Library" et de retrouver l'organisation quotidienne du travail au sein de l'atelier.

H. STACHELBERGER, G. BANIK
(Autriche : Vienne, Académie des Beaux-Arts)

L'utilisation conjuguée de la microscopie optique, électronique et de la microsonde révèle que les taches brunes de plusieurs manuscrits des XVe, XVIIIe et XIXe siècles, issues de la dégradation de la cellulose par l'acide sulfurique en présence ou non d'encre, contiennent aussi du fer qui peut, comme les métaux de transition, intervenir en catalyseur d'oxydation dans la dégradation de la cellulose et des protéines. Les conditions de conservation influent fortement sur la diffusion du fer en particulier l'humidité.

Applications aux objets d'art

Trois communications concernent des applications originales à la broderie hongroise, la sculpture et la céramique glaçurée russes du Moyen-Age.

M. JARO
(Hongrie : Budapest, Musées)

L'examen au microscope électronique et l'analyse par activation neutronique et spectrographique de fils métalliques de la cape de couronnement royale (Hongrie, XIIIe siècle) ont révélé deux techniques de mise en forme, par martelage d'un fil ou découpage de languettes dans une feuille, et diverses compositions d'alliages : or pur ou argent doré. Sur les restaurations du XIXe siècle, la dorure visible sur les faces latérales prouve qu'elle a été appliquée après découpage des languettes. La composition de l'argent est différente de celle des fils d'origine.

L.A. MUZEUS, O.V. YAKHONT, V.S. OKUNKOV, E.I. KALANTAROV
(U.R.S.S. : Moscou)

La stéréophotogrammétrie (SKA 18) a été employée pour restituer, à partir d'anciennes photographies, la forme originale des parties altérées d'un Saint George polychrome en calcaire, réalisé au XVe siècle par Vasily Yermolin. Les coordonnées spectrales de l'objet ont été calculées à partir de 70 points au moyen de systèmes matriciels interactifs basés sur la méthode des moindres carrés.

L.V. KUZNETZOVA, A.B. ORMONT
(U.R.S.S. : Moscou, Ministère de la Culture)

Les céramiques de la Horde d'Or de Stary Orkhey, en Moldavie, sont couvertes d'une glaçure fortement plombifère (0,1 à 0,3 mm d'épaisseur). L'analyse par microsonde électronique (JEOL JBX 5A) y fait apparaître une teneur exceptionnellement élevée en arsenic (de l'ordre de 20 p.cent d'As_2O_3), élément caractéristique de cette production qui donne une clarté particulière au verre d'où son usage actuel en optique.

2ème SESSION : NOUVELLES TECHNOLOGIES

De caractère plus technique, elle sera animée par Monsieur Pieter Meyers, Directeur du Laboratoire du County Museum de Los Angeles.

V.D. DANIELS
(Angleterre : Londres, British Museum)

Description de l'effet Russel, découvert à la fin du siècle dernier et d'autant plus intéressant qu'il est de mise en oeuvre aisée. Le phénomène d'auto-oxydation, mécanisme de détérioration des composés organiques, peut être mis en évidence par l'effet photographique qu'il induit sur un film. L'auto-oxydation d'une feuille métallique (Zn, Al) libère, par exemple, du peroxyde d'hydrogène (H_2O_2) qui traverse une feuille de papier située entre le métal et le film, impressionné selon la trame du papier. D'autres cas d'application sont présentés.

Rayons X

Cinq communications leur sont consacrées. La radiographie est couramment pratiquée dans les laboratoires, l'émissiographie l'est moins dans la mesure où elle nécessite une tension supérieure à 250 kV inutile pour le travail en studio. Certaines adaptations permettent d'améliorer la lecture ou l'interprétation des documents : la stratigraphie, la stéréoradiographie, l'emploi de filtres, de grilles, d'écrans ou d'amplificateurs de brillance. Le traitement de l'image après numérisation des clichés est sans nul doute une méthode d'avenir. Enfin, l'accès aux scanners, encore réservés au domaine médical, et l'apparition de tomographes industriels laissent espérer une pratique plus large de ces techniques de pointe dans les études de conservation.

F. DRILHON
(France : Paris, Louvre)

La radiographie par réflexion ou émissiographie obtenue avec des rayons X durs (> 220 kV), filtrés permet, là où la radiographie est inopérante par manque de lisibilité, d'obtenir une image de la surface d'objets plans telles que peintures sur soie, sur métal (cuivre, étain) ou sur bois recto-verso, rentoilées (colle à la céruse), etc... Elle complète aussi la radiographie pour l'étude des champlevés.

B.A. GOTTLIEB, J. ROBERTS
(Danemark : Copenhague, Musée National)

L'enregistrement radiographique panoramique d'objets cylindriques a nécessité l'adaptation d'un équipement radiographique visible au laboratoire du musée national de Copenhague. L'équipement (Andrex HDR-X) permet de faire des agrandissements et des images panoramiques en une seule exposition. L'emploi de masque central en plomb pour les objets cylindriques évite la superposition d'images. Le choix de l'anticathode accroit le contraste.

F. DRILHON
(France : Paris, Louvre)

L'examen radiographique d'une cinquantaine de sculptures en cire du XVIe au XIXe siècle permet de discerner leur constitution et leur mode d'élaboration, de comparer les oeuvres d'un sculpteur, de constater leur état de conservation et de localiser l'emplacement

des restaurations. La présence d'armatures métalliques dépend de la taille et de la forme des objets. Les techniques sont variées : cire moulée et modelée, modelée en colombins ou sur un pantin articulé, cire sur plâtre ou liège, etc...

P. REIMERS, J. RIEDERER
(Allemagne : Berlin, Musées Nationaux)

L'étude d'objets composites aux matériaux de densités très variables (momie péruvienne à feuille métallique sur le front ; Bouddha en laiton contenant un rouleau de papier, etc...) nécessite l'emploi de la tomographie digitalisée (scanner linéaire). Les sections, recomposées par ordinateur, sont obtenues avec une résolution de densité de l'ordre de 0,1 p.cent.

F. DRILHON
(France : Paris, Louvre)

L'image au scanner permet de reconstituer l'image tridimensionnelle de petits objets en argile contenus dans des bulles sphériques fermées provenant de Mésopotamie. Le nombre, la forme et la dimension des calculi sont l'expression d'un système comptable -non encore élucidé- du IVe millénaire.

Méthodologie

M. SCHREINER, M. GRASSERBAUER, F. MAIRINGER
(Autriche : Vienne, Académie des Beaux-Arts)

L'étude de la dégradation du verre à vitre médiéval a été conduite par spectrométrie de masse ionique. Cette analyse non-destructive fait apparaître, au niveau du premier micron, une différence de composition traduisant les mécanismes de corrosion et la production de gypse et de syngénite.

M. MATTEINI, A. MOLES, G. LANTERNA
(Italie : Florence, Université)

La combustion pyrolytique d'échantillons protéiniques, oléagineux ou résineux évite la préparation d'un prélèvement pour identification par chromatographie en phase gazeuse. Les résultats présentent une reproductibilité satisfaisante grâce à une adaptation spéciale du pyrolyseur.

Datation

Deux communications lui sont consacrées.

P. KLEIN, H. MEHRINGER, J. BAUCH
(Allemagne : Hambourg, Université)

Méthode non-destructive, la dendrochronologie a permis de dater la fabrication de 50 instruments à vent en épicéa et de retrouver les parties de l'instrument faites à partir du même arbre. Lorsque le vernis n'est pas transparent, les cernes sont comptés par radiographie. Le synchroïsme des courbes est obtenu automatiquement par ordinateur grâce au programme CATRAS.

J. CEJKA, I. HRUSKOVA, E. STROUHAL, Z. URBANEC
(Tchécoslovaquie : Prague, Musée d'Histoire Naturelle)

La concentration des os en fluor augmente en général avec l'âge des individus, jusqu'à 20 ou 30 ans. Sur cette base, les auteurs sont parvenus à dater des crânes humains provenant du cimetière d'Abusir près du Caire (1000 ans av. J.C.) à partir de la mesure du fluorure, de la densité et de la perte au feu : humidité (110°C), eau de constitution (180°C), teneur en matériaux organiques (550°C). Ces mesures permettent également d'apprécier l'état du squelette et de déterminer les conditions de conservation appropriées.

Ces travaux illustrent quelques unes au moins des recherches menées, depuis trois ans, dans le domaine de la conservation. Le développement rapide des méthodes a déjà permis d'organiser, à Rome en octobre 1983, la première conférence internationale sur l'application des techniques non-destructives à la conservation des oeuvres d'art (3).

D'autres méthodes d'examen d'usages divers ne seront pas présentées à Copenhague : la thermographie, la bétagraphie, la gammagraphie, les ultrasons, l'émission acoustique, l'interférométrie holographique. Des méthodes moins utilisées pourraient être d'un usage plus fréquent si les équipements lourds étaient rendus plus accessibles aux recherches muséologiques : la neutronographie, la protonographie, l'autoradiographie (4), la tomographie par résonnance magnétique nucléaire, et la tomographie à protons (diffusion nucléaire) (9).

On rappellera que certaines méthodes d'analyse non-destructives permettent d'opérer directement sur l'oeuvre : la microsonde laser à effet Raman (5), la spectroscopie photoacoustique et photothermique (3) (6) (7), la spectrométrie d'absorption infrarouge (3). Enfin, les méthodes nucléaires occupent une place croissante, comme E.V. Sayre et S. Sciuti l'avaient prévu dès 1973 (8).

Les méthodes d'activation (neutronique, protonique, hélionique ou photonique) sont particulièrement adaptées à l'analyse des éléments traces. Le développement des petits accélérateurs tandem permet d'envisager aujourd'hui un transfert de technologie vers la conservation : PIXE, PIGME (analyse élémentaire), Ruttherford Back Scattering (profilage), réactions nucléaires (isotopes), millisonde (microanalyse), spectrométrie de masse (isotopes, datation). D'autres méthodes répondent mieux à l'analyse des matériaux organiques : la chromatographie liquide haute performance couplée au spectromètre infrarouge à transformée de Fourrier, la spectroscopie de résonance magnétique à transformée de Fourrier C^{13} (3), la spectrométrie à résonnance paramagnétique électronique. Ces techniques variées prendront place, selon toute vraisemblance, dans les laboratoires de recherche sur les oeuvres d'art.

Parallèlement aux développements souhaitables, il demeure utile d'agir en commun pour normaliser les méthodes en usage, afin que l'échange internationale des informations puisse se développer, notamment par ordinateur.

Après exploitation du questionnaire sur la réflectographie infrarouge, joint en 1983 à la première lettre d'information du Comité, il parait souhaitable qu'un groupe d'experts élabore, sur ce thème, un programme de travail pour trois ans. Le moment parait venu aussi de susciter la création d'un sous-groupe "traitement de l'image" chargé du développement de méthodes interactives qui après numérisation permettraient une nouvelle approche des oeuvres.

A ces deux propositions, viendront s'ajouter, on l'espère, d'autres voeux formulés par le Comité.

Il reste à souhaiter que l'espoir d'amicale concertation qui anime notre groupe suscite, dans trois ans, une autre floraison d'idées.

BIBLIOGRAPHIE

(1) Monsieur R. Van Schoute organise tous les 2 ans un colloque spécialisé sur le dessin préparatoire des peintures.
Le dernier colloque a eu lieu les 29 et 30 septembre et le 1 octobre 1983, sur le thème : "Dessin sous-jacent et autres techniques graphiques"

(2) Signalons la parution en 1983 d'un numéro spécial de Nuclear Science Applications réservé à l'étude des oeuvres d'art par faisceau d'ions accélérés : PIXE, microsonde nucléaire, PIGME, méthodes d'activation, réactions nucléaires (analyse isotopique), Ruttherford Back Scattering (profilage), spectrométrie de masse (isotopes, datation).
Ion Beam Techniques in Archaeology and the arts
Nucleart Science Applications
Section B - volume 1, number 5 (1983)
Edited by Alexander Zucker - Oak Ridge National Laboratory

(3) First International Conference on "Non-destructive testing in conservation of works of art"
Rome, 27-29 octobre 1983
60 conférences ont été présentées à l'occasion de ce congrès international

(4) Monsieur Pieter Meyers est à l'origine de l'application de l'autoradiographie à l'étude des peintures. Ses recherches réalisées au Metropolitan Museum of Art ont fait l'objet d'une publication.

P. MEYERS
"Art and Autoradiography : Insights into the genesis of paintings by Rembrandt, Van Dyck and Vermeer"
Metropolitan Museum of Art, 1982

(5) B. GUINEAU
Analyse non-destructive des pigments par microsonde Raman laser : exemples de l'azurite et de la malachite
Studies in Conservation, 29 (1984), pp. 35-41

(6) Troisième conférence internationale de spectroscopie photoacoustique et photothermique
Paris, 5-8 avril 1983

(7) Réunion de l'Association franco-hellénique pour la coopération scientifique et technique
Athènes, 17-18 octobre 1983
"Les méthodes physico-chimiques d'analyse des oeuvres d'art (tableaux, icônes, peintures murales..)

(8) Congrès international : "Application des méthodes nucléaires à l'étude des oeuvres d'art"
Rome-Venise, 24-29 mai 1973
Publié par l'"Academia Nazionale dei Lincei" en 1976

(9) Thèse de doctorat d'Université de J.C. DUCHAZEAU-BENEIX
"Radiographie par diffusion nucléaire de protons d'énergies intermédiaires"

SOME PRACTICAL ASPECTS OF THE PREPARATION AND STUDY OF CROSS-SECTIONS

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Abstract

Some practical procedures in the preparation and study of paint cross-sections are described such as removing air bubbles with a needle, omitting polishing, and combining ultraviolet fluorescence with visible incident light for viewing cross-sections are described. Dark-field reflected light observation can be gradually changed to bright-field backgrounds by using an illuminating microscope lamp directed onto the lateral sides of the plastic block containing the sample. The staining of cross-sections is briefly reviewed.

Since Raehlmann first published a cross-section of a sample from a painting early in this century the technique has become widespread in museum laboratories (1). In spite of this increased interest the number of publications dealing with the subject has remained very slight. This may be due to the fact that, for example, Joyce Plesters' classic paper of 1955/56 is still eminently usable (2). Microscopists in this field have undoubtedly in due course developed their own small improvements but these remain usually confined to each individual laboratory. For this reason a few "tricks of the trade" employed by the author are described here in the hope that others may find them useful as well.

1. Samples roughly positioned on the hardened "half-block" can be corrected in the still liquid synthetic material with a needle or pin under the microscope. Air bubbles trapped beneath the sample can be gently removed in this way. A steady hand is naturally required.

2. Polishing on a lap-cloth with alumina is required in metallography but usually leads to part of the softer paint sample being polished out of the harder synthetic embedding material. After cutting and wet grinding of the plastic block with Emery papers 240, 320 and 400 the use of grade 600 paper is quite sufficient to eliminate disturbing scratches. Eventually barium sulphate loaded heavy art paper can be used for final polishing as suggested by Schramm and Hering (3).

3. Grounds containing much glue, secco layers in mural paintings, etc. are sensitive to water. Emery papers 400 and 600 should then be used with kerosene, for example, as the lubricant.

4. Cross-sections can best be viewed in dark-field reflected light. Objectives and condensors are used as developed for metallography. The illuminating light arrives at a low angle at the sample plane to prevent excessive scattering (4). To reduce scattering further some mounting medium should be applied onto the sample in its block. Kerosene as suggested by Plesters is very satisfactory; its wets polyester well and can be wiped off with soft tissue papers leaving no residue. For permanent mounts synthetic Canada balsam Rhenohistol Merck is most suitable. The consequence of this however, is that objectives with a higher numerical aperture than c. 0.3 cannot be used as they are designed for polished metal surfaces without cover glass. Objectives with a higher numerical aperture do not achieve proper focussing when the sample is covered with a mounting medium whether or not with a cover-glass.

5. Observing the cross-section in dark-field reflected light normally leads to a dark background as the word "dark-field" indicates. This is not very satisfactory in the study of paint cross-sections as varnishes and glazes can be better viewed against a light background. This drawback can be overcome by illuminating the lateral sides of the plastic block with a strong light-source such as the microscope lamp of a stereomicroscope. Using white plasticine to press the block parallel to the microscope glass is a preliminary step for achieving this improvement. Modifying the light intensity of the external source provides all the effects necessary for optimal illumination of the sample.

6. Relatively recent improvements in fluorescent microscopy have made incident light fluorescence accessories very useful in the study of paint cross-sections. The author uses a Zeiss incident light fluorescence system with a HBO 50 high pressure mercury source providing ultraviolet excitation (exciter filter G 365) and fluorescence in the entire visible range of the spectrum (barrier filter LP 420). Interpretation of the cross-section viewed in fluorescent radiation alone is not always easy. Therefore the cross-section is simultaneously illuminated at various light levels with the ordinary dark-field incident light set-up. The Zeiss Standard 08 microscope allows for the fluorescence system to be mounted on top of the dark-field incident light attachment (5). In this way the colour of the paint-layers is retained while the fluorescence of varnishes - especially varnishes between overpaint and original layers - is strong enough to be observed at the same time. This method has proved to be very useful for distinguishing between discoloured copper resinate glazes and darkened varnish - a problem encountered frequently in the cleaning of paintings.
Masschelein-Kleiner and Taets (6) identified oil as the main component of a green glaze on a fifteenth century Brussels polychromed sculpture, the resinate being probably made of the copper salt of a pine resin. Masschelein-Kleiner (7) obtained similar results on a sample of a green glaze taken from the meadow in the Van Eyck "Three Maries at the Tomb" (Rotterdam, Museum Boymans-van Beuningen, Cat. 2449). In the cross-section of this sample it can indeed be observed that the resinate glaze does not fluoresce. This observation has been made on samples of other Flemish Primitive paintings as well.

Staining tests on cross-sections. A brief review.

As early as 1905 W. Ostwald (8) used methyl violet to stain for oleaginous media on paint sections and iodeosine for proteins. This approach seems further to have been scarcely attempted. A revival was initiated by Johnson and Packard in their 1971 paper (9). They used Ponceau S for proteins and Sudan Black B for oils. They were unaware of M.C. Gay's somewhat earlier researches; she not only used various staining reagents but also introduced the gradual heating of a thin slice of the sample up to 240 °C (10). Some of the difficulties encountered by Johnson and Packard could be avoided in this way. Later Martin (11) improved her method and described a staining technique using various reagents based on Amido Black. The French workers used a special polyester resin Rhodester which not only allowed cutting with a simple hand-microtome but also remained unaltered when heating up to 240 °C. This resin has been unavailable for some time and the development of a suitable substitute is called for. It is essential that the resin does not melt at lower temperatures as otherwise the characteristic liquifying of the medium cannot be properly observed. The author has used a Projectina Nord temperature control micro heating stage and found the gradual heating of a sample slice to be a reliable and reproducable method for distinguishing between oleaginous and mixed media.
The staining of cross-sections and not of slices of the sample has been advanced by Matteini, Moles and Tosini

(12) who notably developed a method for locating oils with n-butylamine as an intermediary agent. Kockaert and Verrier (13) have used staining on cross-sections with Amido Black and Fuchsine to elucidate the media of Van Eyck. They used cross-sections prepared some 25 years earlier. In using such cross-sections which carry vital information about the colours of the paint-layers the author has found it an advantage to use the technique proposed by Matteini et al. (14): only half the cross-section is stained by employing a fine brush or glass-rod under the stereomicroscope. Tissue paper can be used for wiping the reagents and washing liquids away. The normal colours of the paint layers and the coloration of the stained layers are thus more easily juxtaposed when viewing the treated cross-section in dark-field reflected light at higher magnifications. The original appearance of the section is thus only partially impaired. Although the lack of heating-up possibilities is a drawback it would seem that staining on cross-sections is quite feasible in many cases. It is an advantage that the surface is polished which is not the case with slices cut with a microtome.
Global identification of media in each layer through staining methods should precede investigation with instrumental methods such as gas chromatography.

Notes and references

1. E. Raehlmann, Über die Maltechnik der Alten, Berlin 1910.
2. J. Plesters, "Cross-sections and Chemical Analysis of Paint Samples", Studies in Conservation, 2 (1955/56), 110-157.
3. H.-P. Schramm and B. Hering, Historische Malmaterialien und Möglichkeiten ihrer Identifizierung, Hochschule für Bildende Künste Dresden n.d. (1980) esp., 142
4. The Zeiss microscope used by the author employs Epiplan HD objectives. The principle is described in E.M. Chamot and C.W. Mason, Handbook of Chemical Microscopy, John Wiley, New York 1958, Vol. II, 126, 127.
5. This is possible with the Zeiss Standard 08 microscope used by the author but does not seem to have been envisaged by the manufacturers as the polarizer for incident light cannot be inserted in this position. Other microscopes seem to have only alternative visible and fluorescence viewing.
6. L. Masschelein-Kleiner and P. Taets, "Contribution to the Study of Natural Resins in the Art", Preprints ICOM Committee for Conservation, 6th Triennial Meeting, Ottawa 1981, 81/16/3, 7.
7. Mrs. Masschelein-Kleiner very kindly carried out this analysis at the request of the author and reported the result in a letter to the author dated 2 December 1981.
8. W. Ostwald, "Ikonoskopische Studien. 1. Mikroskopischer Nachweis der einfachen Bindemittel", Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften, 1905 (Erster Halbband), 167-174.
9. M. Johnson and E. Packard, "Methods used for the Identification of Binding Media in Italian Paintings of the Fifteenth and Sixteenth Centuries", Studies in Conservation, 16 (1971), 145-164.
10. M.C. Gay, "Essais d'identification et de localisation des liants picturaux par des colorations spécifiques sur coupes minces", Annales Laboratoire de Recherche des Musées de France, 1 (1970), 8-24. She reported applications at the ICC Lisbon 1972 Congress: M.C. Gay, "Application de la méthode des colorations sur coupes minces à l'étude des liants de quelques peintures Italiennes du XIVe et XVe siècles", Preprints of Contributions to The Lisbon Congress 1972, Conservation of Paintings and the Graphic Arts, 705-713. The English translation (M.C. Gay, "Application of the Staining Method of Cross-sections in the Study of the Media of Various Italian Paintings of the Fourteenth and Fifteenth Centuries", Conservation and Restoration of Pictorial Art, N. Brommelle and P. Smith (ed), Butterworths 1976, 78-83, unfortunately suffers from confusing errors in translation; "coupes minces" should have been translated, for example, with "thin slices". The impression is now given that cross-sections (blocks of plastic) can be heated.
11. E. Martin, "Note sur l'identification des protéines dans les liants de peinture", Annales Laboratoire de Recherche des Musées de France, 1975, 57-60. E. Martin, "Some improvements in techniques of analysis of paint media", Studies in Conservation, 22 (1977), 63-67.
12. M. Matteini, A. Moles and I. Tosini, "Topochemical Reactions for the Recognition of Oil Media in Paint Fragments", ICOM Committee for Conservation, 6th Triennial Meeting, Ottawa 1981, Preprints 81/1/6.
13. L. Kockaert and M. Verrier, "Application des colorations à l'identification des liants de Van Eyck", Bulletin IRPA, XVII (1978/79), 122-128.
14. M. Matteini et al., op. cit. (note 12 above).

TECHNIQUE RADIOGRAPHIQUE GRAND FORMAT APPLICABLE IN-SITU SUR LES TABLEAUX EXPOSÉS ACTUELLEMENT AU MUSÉE DU PRADO

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RESUMÉ

Le grand nombre et la taille de beaucoup de tableaux qui se trouvent au Musée du Prado, ainsi que certains problèmes spécifiques à notre Pinacothèque ont conduit le Cabinet de Documentation Technique du Musée à adopter un système radiographique, adapté à l'étude de nos peintures.

Nous exposons ici les lignes générales du procédé, basé sur l'emploi d'un matériel radiographique clinique. Le montage spécial des plaques permet d'obtenir des radiographies de grand format à partir de raccords à peine perceptibles. Le développement automatique des plaques améliore sensiblement la qualité des résultats.

Ces conditions permettent d'obtenir des radiographies de peintures avec une nette amélioration de la rapidité et de la qualité des plaques, comme nous avons pu le vérifier, au Cabinet Technique, lors d'études récentes sur les Peintures Noires de Goya.

INTRODUCTION

A ses debuts le Cabinet de Documentation Technique du Musée du Prado, en 1979, a adopté le système Cronaflex pour la réalisation de radiographies des peintures. La qualité de ce matériel et des résultats obtenus ont déjà étés rapportés par G. Van de Voorde (1) dont nous avons pu constater la réalité sur les documents obtenus (2).

La première recherche systématique d'une collection au Musée du Prado a été réalisée de 1980 à 1982, sur les 38 peintures du Greco et d'autres tableaux du même auteur prêtés à notre Pinacothéque lors de l'Exposition sur le Greco célébrée en 1982 (3).

La première partie du programme radiographique (4) a été realisée avec le materiel Cronaflex. Mais l'étude de tableaux de grande taille posa des problémes. En raison de leur taille, il était impossible de transporter ces tableaux au laboratoire; de plus nous n'avions pas de salle réunissant les conditions nécessaires pour utiliser le systéme Cronaflex (Obscuritée, distance, etc...).

MATERIEL

Le matériel utilisé est fabriqué par Kodak (X-Omat/S, film pour radiographie médicali), livré en deux versions: Film triple 30 x 30 cm. (30 x 90 cm.) ou 30 x 40 cm. (30 x 120 cm). La découpe est donc réalisée tout les 30 et 40 cms. selon le modèle choisi. Le stokage antérieur et postérieur est très commode, une fois le cliché exposé et révéle.

MONTAGE DES PLAQUES

Bien que l'on puisse monter ensemble autant de bandes que l'on désire selon la taille du tableau, pour faciliter la manipulation, les dimensions les plus grandes sont de 90 x 90 cms. ou 120 x 120 cms. selon les étuis. Il est certain que pour des formats plus petits ou plus grands nous adaptons les étuis et le nombre de plaques à la taille du tableau, en nous basant toujours sur des multiples de 30 cms. (largeur des plaques) (60 x 90, 30 x 90, 60 x 120 cms, etc...).

Dans une chambre obscure avec un éclairage de sécurité (5) nous réalisons le montage de trois feuilles ou plus, fixées entre elles par un ruban adhésif (scotch) transparent (6). Les plaques ont des bords rectilignes et par consequent la juxtaposition parfaite de plusieurs feuilles est facile, même en obscurité. La présence du ruban adhésif est imperceptible sur le r'ésultat final. Ce montage est introduit verticalement dans une enveloppe noire de carton rigide, fermée hermétiquement pour éviter que le film ne soit voilé par la lumière.

IMPRESSION DES PLAQUES

Le montage radiographique a été posè sur chariots afin de pouvoir le déplacer facilement. Le tube de R X est fixé sur une colonne dotée de crémaillère pour pouvoir le positionner à la hauteur désirée.

L'impression d'une plaque de 90 x 90 cms se réalise à une distance de 2,5 métres. Pour des tailles supérieures une plus grande distance est nécessaire, entre le tube et le tableau afin d'obtenir un fais-ceau homogène et un parrallélisme parfait qui faciliteront le montage postérieur d'autres plaques pour des tableaux de grandes dimensions.

Avec ces distances, sur les toiles les conditions techniques pour l'exposition des plaques varient entre 20-25 Kv, 5 a 10 mA, durant 1 a 2,30'. Pour les peintures sur bois les conditions sont de 30 à 45 Kv, 8 à 15 mA et 2' à 3'. Chaque plaque correspond à un tirage et nous réalisons le nombre de tirages nécessaires. Pour cela, nous déplaçons le tube le long de la surface du tableau en surreillant le centrage pour éviter les problemes de parrallélisme des impressions différentes durant le montage du document.

REVELATION

Les plaques une fois exposées sont transportées d ans une salle dotée d'une eclairage de sécurité, où les plaques sont sorties de leurs enveloppes et séparées en supprimant les raccords.

Les plaques sont alors révélées avec une développeuse automatique Kodak X-Omat RPM-7B. En 90 secondes la plaque développée est prête pour étude. Le proc essus de révélation est optimisé (8). De plus, le tirage automatique permet d'obtenir une trés grande uniformitée des plaques, soit un document complet trés satisfaisant.

MONTAGE DU DOCUMENT

On reproduit ensuite le montage des films impressionnés au moyen d'un ruban adhésif de type - scotch (9)appliqué le long des joints, abtenant ainsi les documents de 90 x 90, 120 x 120 cms, etc.... Nous pouvons réunir les plaques en coupant les bords superposés. Comme ces bords sont droits, l'opération est facile et ne laisse pratiquement pas de traces. On peut également laisser les documents tels qu'ils ont été disposés pour la photographie.

A: Goya: "Romería de San Isidro". Détail radiographique: 25 Kv, 10 mA, 2'; distance: 3 mètres.

REPRODUCTION

La reproduction peut se faire de plusieurs façons, selon la technique employée au montage. Nous avons préféré respecter la dimension des plaques en accord avec celle choisie au tirage. La reproduction est faite dans un Mégatoscope de grande taille, en - photographiant les plaques une par une, et en conservant les mêmes conditions, ce qui permet de mieux — respecter les différentes plaques qui forment l'ensemble.

Une fois les copies réalisées sur papier, nous passons au montage final. Il est préferable de faire ce montage sur photos qu'à partir des plaques, la rectification des erreurs de montage est plus facile.

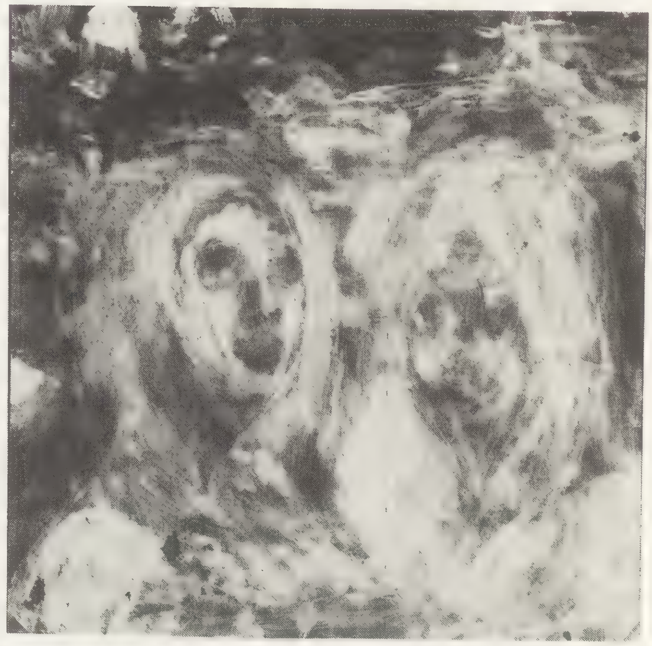
Avec un matériel approprié, on peut également réaliser des copies par contact, révélées par la tireuse automatique (10).

LE STOCKAGE

Le stockage et l'archivage des documents peut se faire de deux façons:

a) Dans des archiveurs spéciaux pour plans, taille maximum de 90 x 120 cms, en respectant les montages réalisés. Le vieillissement du papier adhésif transparent est assez lent et n'abîme pas les plaques.

b) On peut aussi démonter les plaques. Comme nous l'avons signalé, ces plaques sont pré-coupées et leur taille, une fois pliées, ne dépasse pas 30 x 30 — cms. ou 30 x 40 cms.



B: Détail de la même plaque radiographique.

CONCLUSIONS

La bonne qualité des documents, la facilité et la rapidité du procédé, face au travail intense du Musée, justifie pleinement le choix de cette méthode. Nous pouvons faire appel à d'autres méthodes pour des cas exceptionnels.

Ces derniers mois, nous avons pu vérifier - la qualité et la vitesse d'exécution des documents radiographiques sur 14 peintures noires de Goya conservées au Musée du Prado dont quelques-unes sont de — très grandes dimensions. Toutes ces peintures sont fixées au mur des salles du Musée. Elles décoraient les murs de "la Quinta del Sordo", résidence de Goya à Madrid (11).

Ces documents radiographiques, permettent - d'étudier en détail le tracé du pinceau et d'autres - caractéristiques techniques du peintre employées dans ces oeuvres. De plus, les radiographies révélent l'état de conservation des peintures lié à deux raisons principales: le transport réalisé et les restaurations entreprises à différentes époques.

Les radiographies ont également permis des découvertes dans les changements de compositions et -

les transformations des peintures qui peuvent nous - amener, dans certains cas, à étudier à nouveau leur signification. Quelques changements furent réalisés par Goya et sont identifiables par la superposition des compositions et les différentes densitées, tels que les transformations mises en évidence dans les - tableaux "Les vieux mangeant leur soupe", "Le duel à coups de bâtons", "Le pélerinage à la source de San Isidro" par example. Dans d'autres cas, les modifications ne sont pas dues à l'auteur mais correspondent à des restaurations postérieures. Ces tableaux sont actuellement dans un état de conservation très pré-- caire (12). Enfin, d'autres cas, tel celui de "Saturne dévorant ses enfants" dont les changements sont - dus d'une part au peintre et d'autre part à des modifications postérieures.

C: Goya: "El aquelarre". Détail radiographique: 25 Kv, 10 mA, 2'; distance: 3 mètres.

D: Détail de la même plaque radiographique.

NOTES

(1) G. Van de Voorde: Het gebruik van Cronaflex film, voor de radiografie van schilderigen dans "Bulletin de l'Institut Royal du Patrimoine Artistique", XIV, 1973-74 (1975), pp. 34-38.

G. Van de Voorde, A note on the Radiography of - large size Paintings, dans "Studius in Conservation", 20, 1975, pp. 190-194.

(2) Le Cabinet de Documentation Technique du Musée - du Prado a obtenu de nombreux documents par le - système Cronaflex: Descente de Croix de Roger -- Van der Weyden, 15 tableaux du Greco, les 4 ta-- bles de Fernando Gallego, etc...

(3) Exposition "Le Gréco de Tolède" réalisée au Mu-- sée du Prado, Toledo Museum of Art, National Gallery of Art de Washington et Dallas Museum of -- Fine Art d'Avril 1982 à Février 1983.

(4) Nous avons réalisé les 15 radiographies du Greco avec le Cronaflex (Collection du Musée du Prado). La méthodologie suivi au Musée, mis à part l'étude radiographique, s'est basée sur une étude de réflectance par infrarouge et fluorescense ultraviolette, ainsi que l'analyse des matérieaux -- (supports, préparations, pigments, etc...).

(5) L'éclairage de securité employé est le suivant: Lampe Kodak circulaire de 14 cms, filtre de sureté Kodak GBX-2 circulaire de 14 cms.

(6) Il faut que le ruban adhésif soit en bonnes conditions, afin d'éviter qu'il laisse des traces - superficielles sur la plaque radiographique.

(7) Les produits chimiques employés dans le tirage - automatique sont: Révélateur Régénéré RPX OMAT
Fixateur Régénéré RPX OMAT

(8) Le document radiographique complet d'un tableau qui a, par exemple, une taille de 4m x 2m, peut être réalisé et prêt pour étude en deux à trois heures, selon l'habitude de la personne qui est chargée de ce travail.

(9) Le ruban adhésif normal vieillit très rapidement et nous ne conseillons pas son emploi.

(10) Les copies contact des radiographies peuvent se faire avec du matériel Kodak X-OMAT duplicating film par exemple. D'autres méthodes de reproduction peuvent être employées. On peut consulter une revue de ces méthodes dans le texte de D. - Hollanders Favart et R. Van Schoute "La conservation des radiographies" (Le Comité pour la Con-- servation de l'ICOM, 6ème. réunion triennale, -- Ottawa, 1981, pp. 6-8).

(11) Sánchez Cantón, F.J.: Goya y sus pinturas negras en la Quinta del Sordo. Barcelona-Milán, 1963.

(12) En Novembre 1983, un Symposium s'est organisé au Musée du Prado pour traiter des problèmes de Conservation de ces peintures.

ETUDE DE LA TECHNIQUE PICTURALE ET DU DESSIN SOUS-JACENT DE QUELQUES TABLEAUX DE RAPHAEL

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RESUME

Une étude a été conduite au Laboratoire de Recherche des Musées de France sur les oeuvres de Raphaël, conservées dans les collections françaises, à l'occasion du 5ème centenaire de la naissance du maître ; une synthèse des résultats, portant sur la technique picturale et l'observation du dessin sous-jacent, est ici présentée :

- examens radiographiques et analyses physicochimiques des couches picturales ont permis d'utiles observations sur la préparation des supports, la stratigraphie des couches, la nature des pigments et des liants, et ont mis en évidence parfois des reprises du peintre, toujours une recherche constante de perfection : mélange raffiné de pigments pour exécuter les carnations, effets savants obtenus par des superpositions de glacis ;

- photographies infrarouges et réflectogrammes ont révélé le dessin sous-jacent : exécution libre et spontanée au charbon ou au pinceau ; report de cartons (poncifs) ; collaboration éventuelle entre maître et élèves ; repentirs.

A l'occasion du 5ème centenaire de la naissance de Raphaël, chaque musée, chaque ville conservant au moins l'une de ses oeuvres, l'a célébré durant l'année 1983 (1).

En ce qui nous concerne, nous nous bornerons à présenter l'apport des examens technologiques effectués au Laboratoire de Recherche des Musées de France sur les quelques tableaux conservés dans les collections françaises ; certains pratiquement intacts, d'autres transposés ou abondamment restaurés, tous cependant ont révélé sous ces investigations des enseignements, des normes qu'il parait utile de transcrire et de confronter à d'autres études.

Sur le plan des supports -à l'exception de deux oeuvres exécutées sur toile, "Balthazar Castiglione" et "Raphaël et un ami", et celles aujourd'hui transposées, toutes sont peintes sur panneau de bois : peuplier par excellence (essence dominante en Italie et utilisée par les peintres de cette époque). Le soin particulier apporté au montage de ces panneaux retient l'attention. Les supports de petit format ne sont constitués que d'une seule planche, bien choisie, sur dosse ou entre quartier et dosse.
Les supports de grand format sont constitués de plusieurs planches (le diamètre du tronc de peuplier est faible) assemblées à joints vifs ; sur chaque joint, une bande de toile renforce cet assemblage et dans plusieurs cas observés, une autre bande intercalée ponctue et augmente la solidité et la planéité de la préparation dans laquelle ces bandes sont incluses ("l'Ange" du Louvre, "La belle jardinière", "La madone de Lorette" de Chantilly, "La Vierge" et "Dieu le Père" du musée de Naples). Cette particularité a permis de situer "l'Ange" du Louvre par rapport à la "Vierge" dans l'essai de reconstitution du Retable de Saint Nicolas de Tolentino.

Les analyses de matière picturale (2) opérées sur les quelques tableaux des collections françaises ont donné lieu aux observations suivantes :

- la préparation est une épaisse couche de gesso blanc : mélange de sulfate de calcium et de colle animale ; c'est la préparation traditionnelle des écoles italiennes. Pour des raisons de prudence et de non altération trop profonde, il n'est pas possible d'évaluer l'épaisseur du gesso, celui-ci n'étant jamais prélevé dans sa totalité. Après avoir été finement polie, cette préparation est recouverte d'un mince film d'huile (huile de lin dans le cas des oeuvres analysées) ;
- vient ensuite ce que l'on appelle une couche d'impression, mais que je nommerai de préférence une ébauche de mise en place de couleur, car cette couche n'est pas homogène ; elle est diversement colorée et à base de blanc de plomb mêlé soit de charbons broyés pour obtenir un gris clair, soit de jaune de plomb et d'étain, soit de minium pour obtenir une nuance plus chaude (cette couche d'impression varie de 30 µm à 80 µm) ;
- les couleurs interviennent ensuite :
  . les bleus sont généralement de l'azurite enrichi de lapis lazuli (Madone de Lorette) ou de lapis pur (La belle jardinière).
  Sur une oeuvre plus tardive (La Grande Sainte Famille) le lapis repose sur une couche rose vif. Est-ce une innovation de la part de Raphaël ou une technique due à son atelier ? Nous avons retrouvé cette couche rose sous la "Madone au voile" et ceci influe sur la tonalité finale du bleu ;
  . les rouges sont généralement des couches opaques à base de laque rouge (30 µm environ) recouvertes de glacis également rouges plus ou moins minces ; ils sont homogènes et transparents et leur superposition peut atteindre 70 à 80 µm ;
  . les carnations sont soigneusement préparées et travaillées ; elles sont constituées de blanc de plomb nuancé par addition de pigments rouges (vermillon le plus souvent finement broyé) et parfois quelques grains de charbon noir.
  Raphaël se plait à les enrichir en y mêlant d'autres pigments : lapis, jaune au plomb et à l'étain, minium. Tous très finement broyés, ils sont mêlés en faible quantité au blanc de plomb de façon très homogène. Il s'agit là d'une élaboration particulièrement savante et subtile chez Raphaël pour modeler habilement ombres et lumières dans les chairs. Cette couleur, posée en une ou plusieurs couches, atteint généralement 50 µm ;
  . les verts sont obtenus par le mélange de bleu d'azurite et de jaune au plomb et à l'étain (technique chère aux primitifs italiens).
  La profondeur et la luminosité recherchées sont obtenues chez Raphaël par des effets savants de superposition de couches : glacis homogènes posés successivement et dont les nuances vont d'un vert-jaune clair à un vert de plus en plus foncé. C'est le cas pour "La belle jardinière", la "Grande Sainte Famille", la "Madone de Lorette"... Cette superposition peut atteindre 100 0 120 µm.

A l'exception des oeuvres transposées ou peintes sur toile, les films radiographiques sont bien lisibles (3) ; ils montrent le montage du support recouvert d'un épais gesso, les modelés délicats des chairs, les contours précis indiqués le plus souvent par un tracé sombre constituant une réserve à l'intérieur de laquelle l'artiste pose ses couches colorées avec un mouvement de brosse qui accuse le sens de la forme recherchée ("Saint Georges", "l'Ange", "La belle jardinière"). Les repentirs révélés sous ces rayons sont rares ("Petit Saint Michel" (4), "La Madone de Lorette" (5)) ; parfois des transformations en cours d'exécution ("Jeanne d'Aragon" (6), "Portrait de jeune femme de Strasbourg" (7)) ou un ajout plus tardif ("La Madone de Lorette" (8)).

L'infrarouge, exploité sur photographie ou en réflectographie, joue un rôle très important dans la recherche de la manière dont Raphaël a élaboré ses tableaux. La mise en place préparatoire, le poncif, le dessin sous-jacent, ont pu en effet être retrouvés sur certains tableaux grâce à ce procédé. Toutefois, nous restons très prudents sur le problème de report de carton ou dessin.

L'observation attentive de deux dessins conservés au musée de Lille montre :

- points reliés par un trait souple, habile, dont l'aisance, bien qu'il suive le pointillé, prouve le maître ("Tête d'homme barbu regardant vers le haut") (fig.1)

Figure 1 : "Tête d'homme barbu regardant vers le haut"
Musée des Beaux-Arts de Lille
Le pointillé à la pierre noire ayant servi au tracé des contours indique le report à partir d'un autre dessin.

- dessin perforé pour un report : les points sont distants d'au moins 4 millimètres ("Tête d'homme âgé vue de trois-quart à gauche") et le diamètre des perforations est d'environ 4/10ème de millimètre (fig. 2).

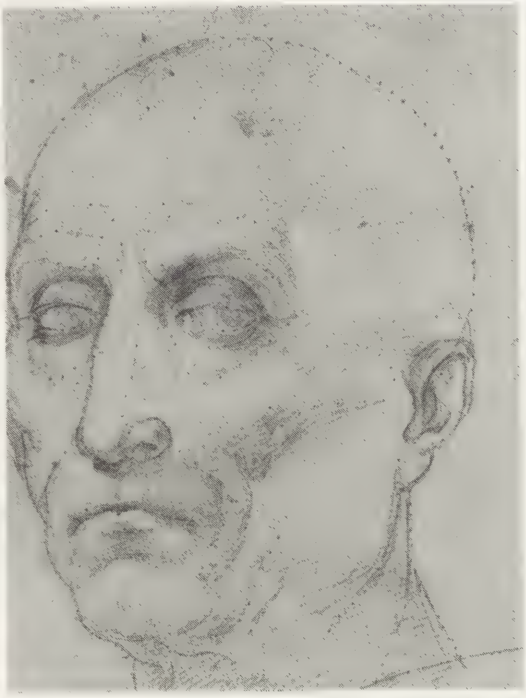

Figure 2 : "Tête d'homme âgé, vue de trois-quart à gauche"
Musée des Beaux-Arts de Lille
Dessin perforé, donc prévu pour un report.

Sur le petit "Saint Georges", une mise en place préparatoire est bien perceptible : reprise autour de la tête du cheval, mise en place rapide de la musculature du poitrail ; ce dessin est exécuté au charbon (fig. 3).

Figure 3 : détail de "Saint Georges luttant avec le dragon"
L'infrarouge met en évidence le dessin libre du cheval, dessin plus ou moins respecté lors de l'exécution finale, et une reprise des contours de la tête.

Sur "La Madone de Lorette", le dessin est également bien restitué, mais il est apparemment fait au charbon (nous utilisons sans doute ici un terme impropre : il est en effet difficile d'effectuer un prélèvement au niveau même du dessin afin d'en faire l'analyse ; pour nous, le terme "charbon" peut être du fusain, du crayon, de la pierre noire, autre en tous cas qu'une couleur posée au pinceau ou une encre) et le trait accroche parfois la préparation, si polie soit-elle ; nous éliminons l'hypothèse d'un poncif (fig. 4).

Figure 4 : dessin sous-jacent retrouvé sur la "Madone de Lorette" du musée de Chantilly
Détail en infrarouge.

Par contre, à ce jour, les éléments retrouvés du "Retable du couronnement de Saint Nicolas", "l'Ange" du Louvre, celui de Brescia, "la Vierge", ne révèlent ni sur photographie infrarouge ni sur réflectogramme de dessin sous-jacent ; le fragment de "Dieu le Père", en revanche, révèle à la partie inférieure, sur les angelots du bas, un poncif évident, raide, ponctué (fig. 5), alors que la figure du Père, admirablement structurée, les angelots de chaque côté, en dépit de leurs altérations, montrent une spontanéité d'exécution, nulle hésitation, l'écriture digne d'un grand maître.

Figure 5 : poncif retrouvé sur l'ange de l'angle inférieur gauche du fragment de Père Eternel du Retable de Saint Nicolas de Tolentino
Détail en infrarouge.

Dans la "Madone d'Orléans" du musée de Chantilly, nous avons retrouvé un poncif, également sec et très appliqué. Est-ce le fait d'un travail de jeune débutant ? (fig. 6).

Figure 6 : "La Madone d'Orléans" - Musée de Chantilly
Détail en infrarouge révélant un report de carton.

"La belle jardinière" demeure dans nos collections un exemple de subtilité, de finesse, d'étonnante habilité dans la reprise des contours, en particulier le visage de la Vierge.

Le repentir de Jeanne d'Aragon fut à l'évidence une reprise au pinceau : le trait large et fluide de l'oeil en est la preuve (fig. 7).

Figure 7 : reprise au pinceau de l'oeil et du sourcil de "Jeanne d'Aragon"
Détail en infrarouge.

Un exemple de dessin retrouvé, après une ample transformation, fut révélé par l'examen en infrarouge des "Trois Grâces" du musée de Chantilly, examen mettant en évidence une pensée première du peintre, essentielle à la compréhension du tableau (9) (fig. 8).

Figure 8 : l'infrarouge a permis de retrouvé l'évolution de la pensée de Raphaël sur le thème des "Trois Grâces" du musée de Chantilly, en mettant en évidence les nombreux changements effectués en cours d'exécution.

Dans la figure centrale, plusieurs changements sont observés : courbes du fessier plus hautes, modification le long de la colonne vertébrale, le bras droit repose sur l'épaule gauche de la divinité à senestre ; sur son épaule droite, un dessin de doigts atteste également un changement d'attitude. En ce qui concerne la divinité de droite, primitivement son bras gauche descendait le long du corps, la main repliée en un geste pudique : il s'agissait alors vraisemblablement de la chasteté.
Sur la figure à dextre, le voile de pudeur se prolongeait sur le fond du paysage.
Si l'on observe ces premières attitudes, seule la divinité de gauche pouvait tenir une pomme et elle n'a subi aucune transformation. Par contre, la composition était déportée vers la gauche ; Raphaël la reéquilibre en modifiant essentiellement les bras et place une pomme d'or dans la main de chaque divinité (il ne s'agit plus alors des trois grâces inspirées du groupe antique mais des Hespérides.

CONCLUSION

Cette synthèse de résultats sur la technique picturale de Raphaël, bien que sommaire puisque volontairement limitée à quelques tableaux indiscutés de Raphaël conservés dans les collections françaises, mérite d'être enrichie par des études similaires conduites dans d'autres laboratoires de musées.
Nul doute que la somme des résultats ne contribue à affirmer la recherche constante de perfection voulue par Raphaël tant dans la création que dans l'élaboration de ses oeuvres, retrouvée aujourd'hui grâce à une nouvelle approche que permettent les techniques scientifiques actuelles.

NOTES

(1) A Paris, Raphaël dans les collections françaises Catalogue - Exposition Grand Palais, 15 nov. 1983-13 fev. 1984

(2) Les analyses ont été effectuées par J.P. Rioux, chimiste au Laboratoire de Recherche des Musées de France

(3) Les documents photographiques et radiographiques ont été effectués par le service du Laboratoire de Recherche des Musées de France sous la direction de A. Tournois

(4) Réduction des remparts de la ville

(5) Reprise du pied droit de l'Enfant

(6) Direction du visage et du regard modifiée

(7) Le visage apparait plus allongé sur le film ; le corselet de la robe remontait davantage sur la chemise qui elle-même, légèrement échancrée dans le dos, s'arrêtait au ras du cou

(8) Ajout du personnage de Joseph à senestre Catalogue - Exposition "La Madone de Lorette" - Les dossiers du Département des Peintures - n° 19 - Musée Condé à Chantilly - oct. 1979, jan. 1980 - pp. 55-62

(9) Hommage à Raphaël - Musée Condé à Chantilly - Catalogue d'exposition - nov. 1983, mars 1984

PANNEAUX D'ARTISTES DES MARCHES DU XVme SIECLE DE LA PINACOTHEQUE DE BRERA: ETUDE DES MATERIAUX ET DES TECHNIQUES

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RESUME

Les méthodes de microscopie optique,de diffraction X, fluorescence X et réflectographie IR ont été appliquées à l'étude des matériaux et des techniques utilisées dans un ensemble de panneaux de peintres des Marches du XVme siècle, conservés à la Pinacothèque de Brera.

Oeuvres analysées:
- Andrea di Bartolo: Polittico dell'Incoronazione
- Bartolomeo di Tommaso da Foligno: Madonna col figlio ed angeli
- Nicolò di Liberatore dit l'Alunno: Polittico di Cagli
- Francesco di Gentile da Fabriano: Stendardino
- Girolamo di Giovanni: Polittico di Gualdo Tadino
- Giovanni d'Angelo di Antonio (Maestro delle Tavole Barberini): S. Pietro
- Carlo Crivelli: Incoronazione della Vergine; S. Antonio; Polittico; Madonna col bambino; S. Pietro Martire; Cristo Morto.
- Vittore Crivelli: S. Chiara e S. Francesco; S. Filemone e S. Giuseppe; S. Giovanni Evangelista; Madonna
- Pietro Alemanno: Polittico

1. Introduction: objectifs et méthodes

Cette étude a été exécutée dans le but d'identifier les matériaux et les techniques d'exécution d'un ensemble de plus de quarante panneaux d'artistes des Marches du XVme siècle (ou s'y rattachant), ensemble d'oeuvres de la pinacothèque de Brera, dont la restauration était alors (1979) envisagée.

De façon plus detaillée, les éléments formant l'objet de nos identifications sur tous les panneaux étaient les suivants:
- les espèces ligneuses constituant les planches des panneaux;
- la nature des toiles collées sur le bois des planches;
- la préparation;
- la couleur, étendue sur la préparation en une ou plusieurs couches.

Vu le grand nombre des panneaux examinés nous avons pensé qu'il aurait été peut-être possible de classer les données receuillies de façon à obtenir des corrélations intéressantes.

Nous avons en fait essayé d'établir une corrélation sur la base d'une subdivision temporelle des différents artistes, artistes que nous avons classés de la façon suivante:

- artistes de la première moitié du XVme siècle: le siennois Andrea di Bartolo et Bartolomeo di Tommaso da Foligno;
- artistes des Marches antérieurs aux Crivelli: Nicolò di Liberatore dit l'Alunno, Francesco di Gentile da Fabriano, Girolamo di Giovanni e Giovanni d'Angelo da Camerino - le maître des"tavole Barberini" -;
- Carlo et Vittore Crivelli et, à leur suite, Pietro Alemanno.

L'examen d'un si grand nombre d'oeuvres de la même époque et de la même région géographique nous a conduit à la mise au point d'une méthodologie utilisant uniquement des techniques d'analyse simples, bien adaptées au type d'étude systhématique qui était requis.

En effet, les méthodes trop complexes, d'application difficile, ou de puissance disproportionnée par rapport au but, ont été écartées.

Les techniques analytiques que nous avons retenues ont été les suivantes:

- bois: deux méthodes de microscopie optique ont été utilisées: une par section, l'autre par macération. Cette dernière méthode a été utilisée sur des échantillons très petits pour lesquels la première méthode n'était pas applicable;
- toile: l'identification des fibres a eu lieu au moyen d'observation au microscope optique en lumière réfléchie et transmise. Les fibres ont été observées longitudinalement et suivant des sections transversales;
- préparation: l'identification minéralogique des composants de la préparation a été obtenue par diffraction X;
- couleur: l'analyse de la couleur a été conduite en deux phases:
  - i) observation au microscope soit de fragments (sur lesquels des tests microchimiques ont été aussi effectués), que de sections transversales d'échantillons englobés en résine;
  - ii) analyses par fluorescence de rayons X, exécutées par les techniques suivantes qui sont dans notre cas, en un certain sens complémentaires:
    - à la microsonde électronique sur section d'échantillons (analyse X.R.F. ponctuelle)
    - par excitation au moyen d'une source radioisotopique, directement sur le tableau (analyse globale).

Du point de vue strictement technique, l'analyse stratigraphique exécutée au microscope optique et à la microsonde électronique semblent se présenter commes les méthodes les plus aptes à répondre aux nombreuses questions posées par notre travail.

L'inconvénient de ces méthodes de grande sensibilité, réside dans la necessité d'utiliser des échantillons prélevés directement sur les tableaux, échantillons qui sont en général et pour cette raison en nombre plutôt limité.

On voit donc l'avantage d'utiliser l'analyse XRF, non destructive, par excitation radioisotopique. Cette méthode, même si elle n'est pas en mesure de fournir des informations complètes sur la nature des pigments et de leur distribution dans l'épaisseur de la couche picturale, donne toutefois immédiatement une indication globale sur la composition élémentaire de la zone irradiée.

En plus de ces méthodes, que l'on peut considérer comme "standard", nous avons également employé, dans un seul cas, la réflectographie I.R. (Carlo Crivelli: "L'incoronazione della Vergine").

Cette technique est, comme l'on sait, très importante pour l'historien de l'art car elle est en mesure de révéler le dessin sous-jacent (Photo 1,2).

Il nous semble également intéressant de remarquer que cette technique est aussi en mesure d'indiquer les zones repeintes (Photo 3) ainsi que les détails des jointures entre les planches (Photo 4).

Certes, ces particularitàs peuvent être vues également bien par d'autres techniques. La réflectographie I.R. présente dans notre cas l'avantage d'un vision pratiquement immédiate et la possibilité d'enregistrement permanent sur bande magnétique. En outre, par un jeu de filtres, les zones repeintes peuvent être, suivant les cas, meiux différenciées. Enfin, avantage non négligeable, le tableau peut être examiné sans déplacement.

2. Résultats

Les résultats de nos observations ont été réunis dans divers tableaux récapitulatifs, concernant les materiaux identifiés (bois, toiles, préparation, couleur) suivant les différents auteurs, etc. En particulier les résultats des analyses de diffraction et fluorescence X sont reportés dans des tableux et des spectres.

Il ne nous est pas possible ici, pour des raisons de place, de nous référer directement à ces résultats qui sont toutefois à la disposition des personnes intéressées. Nous nous limitons donc à une description des résultats de caractère plus général.

Bois. L'examen concerne 54 fragments ligneux provenant des tableaux de six auteurs: Nicolò Alunno, Pietro Alemanno, Carlo Crivelli, Vittore Crivelli, Francesco di Gentile da Fabriano, Girolamo di Giovanni.

Les échantillons proviennent soit des bois originaux, soit des boix utilisés pour les restaurations successives.

Les espèces ligneuses de 54 fragments ont été identifiées. Dans la plupart des cas les peintres ont utilisé Populus nigra, essence déjà présente à l'époque dans la région des Marches et par conséquent d'utilisation facile et économique.

La présence d'écorce a été observés dans le polyptique de Pietro Alemanno. La plupart des échantillons prélevés sur cette oeuvre est de Tilia platiphyllos, essence naturalisée

Photo 1 - Carlo Crivelli: Incoronazione della Vergine (Brera, Milano).
Les mains de Sainte Catherine et de Saint Jean Baptiste en réflectographie I.R. On observe nettement le dessin sous-jacent (o).

Photo 2 - Carlo Crivelli: Incoronazione della Vergine (Brera, Milano).
Draperie sur le pied du Christ. La réflectographie montre bien les ombres exécutées au pinceau après le dessin.

(o) Les photos des rèflectographies sont de Monsieur Dante Pini de la Surintendence aux biens artistiques et historiques de Milan (dans l'ordre d'archive: 84143, 4, 2,1/RF)

en Italie depuis l'antiquité, et donc également d'utilisation facile.

En ce qui concerne les restaurations, probablement post-napoléoniennes, les restaurateurs n'ont pas pensé d'utiliser les mêmes espèces originales mais ont en général employé des essences différentes: principalement Abies alba, Picea abies et, en un cas, Pinus montana; Juglans regia a été utilisé pour une traverse de consolidation dans le polyptique de Girolamo di Giovanni.

On remarque des vermoulures dues à des insectes xylophages (toutefois éliminés depuis longtemps par fumigation). On observe également, surtout au bord des vermoulures, des traces d'anciennes attaques mycétiques.

Toile. Sept échantillons de toile, provenant de Girolamo di Giovanni, Carlo Crivelli, Vittore Crivelli, Pietro Alemanno, ont été examinés. Il s'agit de toile de lin blanc. Le tissu de lin employé par Carlo Crivelli est d'une texture beaucoup plus fine.

Préparation. Onze échantillons de préparation provenant de différents artistes ont été examinés par diffraction X. Il s'agit de gesso avec présence d'anydrite, très marquée celle-ci dans un prélèvement de Girolamo di Giovanni. On remarque la présence dans certains échantillons de traces de gesso hémihydraté, de quartz et de calcite.

Couleur (o) 102 échantillons ont été examinés. 46 plages des oeuvres de Pietro Alemanno et Vittore Crivelli, ont été analysées par X.R.F. non destructive. L'objectif de déterminer les matériaux originaux et les parties repeintes a été atteint. Les résultats particuliers pourraient être utilisés aux fins d'une éventuelle restauration ou comme élements d'un ensemble statistique de données se rapportant aux peintres des Marches du XVme siècle.

En ce qui concerne l'hypothèse de classification temporelle en trois groupes des artistes en question, nous n'avons par remarquée en général de différences substantielles, qui auraient justifié pleinement un tel classement.

Les remarques suivantes peuvent présenter toutefois un certain intérêt. Le premier groupe montre l'usage de techniques tout à fait traditionnelles, tel que l'emploi d'une couche fine de blanc de plomb sur la préparation, ou l'emploi d'outremer naturel dans le manteau de la Vierge et de glacis de laque rouge sur le vermillon.

Les peintres du second groupe semblent utiliser une technique plus simple. Une seule couche de couleur sur la préparation sans "priming" de blanc de plomb et sans "velature". Les pigments sont ceux habituels: vermillon, azurite, les ochres. Girolamo di Giovanni emploie également le vert-de-gris (manteau de Saint Laurent) et utilise la laque de rouge (manteau de Saint Sébastien) au violet (manteau de la Vierge) jusqu'aix tons plus foncés de "biffo" (manteau de Sainte Catherine) en union

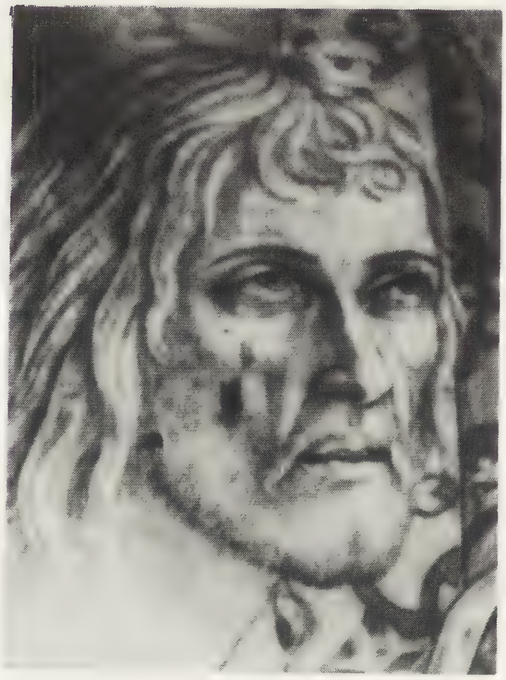

Photo 3 - Carlo Crivelli: Incoronazione della Vergine (Brera, Milano).
La réflectographie met ici en évidence une petite zone repeinte sur la joue de Saint Jean Baptiste.

Photo 4 - Carlo Crivelli: Incoronazione della Vergine (Brera, Milano).
La jonction des planches, qui est d'ailleurs visible en lumière normale, est ici particulièrement exaltée par la réflectographie.

(o) Un examen préliminaire des liants a montré qu'il s'agit de tempere. Une etude plus détaillée est envisagée.

avec l'azurite plutôt qu'avec l'outremer naturel, comme suggéré par Cennino Cennini. Il s'agit d'un spectre de couleurs plus étendu.

Le rouge de l'ange de Nicolò Alunno présente un vernis avec particules d'or qui est probablement authentique.

En ce qui concerne le troisième groupe (les Crivelli et Pietro Alemanno), nous donnons ci-après quelques exemples d'usage particulier des techniques traditionnelles.
Chez Carlo Crivelli, par exemple, (lunetta du Cristo morto) un effet de grande profondeur est obtenu en recouvrant une fine couche transparente contenant quelque particule de laque rouge avec une couche épaisse et homogène d'une très belle laque rouge. C'est une technique raffinée qui ne s'observe pas dans les autres tableaux examinés.

Vittore Crivelli emploie l'indigo pour le bleu clair (que le vernis altéré fait apparaître vert) pour la veste de Sainte Claire et le manteau de Saint Joseph; le vert-de-gris pour les feuilles du grenadier et uniquement l'azurite pour le manteau de la Vierge.

La particularité du polyptique de Vittore Crivelli est que chaque panneau est presque entièrement doré dans sa moitié supérieure (sauf le panneau de la Vierge qui est presque entièrement doré), avec les figures peintes directement sur la dorure.

Cette façon d'opérer est assez singulière puisque, en général, l'or borde les figures, la couleur pouvant se superposer à l'or tout au plus le long des contours des figures mêmes. Peut-être, l'intention de l'artiste fut d'obtenir,de cette façon, une plus grande richesse de couleur. Une autre particularità de Vittore consist à employer un vert de cuivre dans les incarnats et dans les ombres de la veste blanche de la Vierge (o).

Pietro Alemanno ne semble pas abandonner tout à fait l'usage traditionnel de l'outremer naturel pour le manteau de la Vierge. Il en emploie une petite quantité, quelques gros cristaux de lapis-lazuli mélangés à l'azurite de granulométrie plus fine que celle abituellement employée. Dans la Résurrection il utilise la feuille d'argent pour les cuirasses des soldats. Le fond de ce panneau est également doré.

3. Conclusions et remerciements

Les données recuillies au cours de notre étude permettent d'esquisser une description sommaire des techniques utilisées dans les ateliers des Marches au cours de la période en question.

A cet égard, et pour une étude plus complète, l'emploi extensif de la réflectographie IR nous semblerait très prometteur. Cette technique, que nous avons appliquée à un seul panneau, peut en effet montrer, en plus du dessin sous-jacent, nombre de particularités d'intérêt pour la détermination de la technique picturale (Photo 2).

Nous remercions Monsieur Paolo Venturoli, directeur à la Surintendance aux biens artistiques et historiques de Milan, qui a proposé et suivi avec attention cette étude. Nous remercions également Madame Grazia Dassù, directeur du centre C.N.R. "Gino Bozza" du Politecnico de Milan, auprès duquel nous avons exécuté une partie des examens de laboratoire. Nous devons rappeler aussi et remercier l'Institut de Physique Générale Appliquée de l'Université de Milan, qui a mis à notre disposition les appareillages de réflectographie IR et de fluorescence X induite par sources radioisotopiques; ainsi que la Mademoiselle Giulia Deiase, Monsieur Aldo Materassi et Monsieur Roberto Bonecchi pour l'aide apporté au cours des mesures.

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(o) Nous avons observé un emploi analogue d'un vert de cuivre par Raffaello dans lo Sposalizio della Vergine (C.Bertelli et al."Lo Sposalizio della Vergine di Raffaello",Treviglio (1983), 61).

ON THE CONTROL OF COLOUR CHARACTERISTICS IN RESTORATION PROCESSES

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SUMMARY

The possibility of employing a colorimeter of the distance type for measuring the colour characteristics of painting art works is shown. The colorimeter makes it possible to determine the chromaticity co-ordinates x and y and the luminous reflectance Y (%). The object can be at the distance of I50 mm from the head of the colorimeter and farther, the minimum diameter of the part measured being I mm. In measuring the colour characteristics of a picture painted in oil, the chromaticity co-ordinates repeatability obtained was ±0.002 and that of the luminous reflectance ±4 %. The colorimeter was used for measuring the colour characteristics of the samples from the Middle Asian wall paintings and for estimating the changes of these characteristics in restoration work. It was also applied to check the effect of the disinfection treatment with methyl bromide on paints.

That there is a need for an objective fixation of colour changes in works of art both in the course of natural ageing and during restoration work is becoming more and more obvious. It is known that as far back as I930s a visual colorimeter Lovibond was used for this purpose (I). A spectrophotometer of the distance-type constructed by W.D.Wright and M.P.Wassall has been used during the last decade in the London National Gallery (2-4). In our work we made use of a distance colorimeter elaborated in the State Optical Institute named after S.I.Vavilov. It was for the first time employed in the studies of the man skin colour (5). "Potrait of a Woman" by an unknown author (canvas, oil) was taken as an object to find out the possibility of applying this colorimeter for measuring the colour of paintings.

The change field diaphragm placed in the focal plane of the colorimeter's objective made it possible to measure the areas of the object of I mm and more in diameter, the distance from the edge of the head of the colorimeter to the object being about I50 mm. The area to be measured was chosen with the help of a viewfinder arrangement. According to the technique worked out, the area was marked as a circle of a corresponding size on a special transparent screen (a film), placed before the object. When the measurements were repeated the screen position was restored precisely according to the details characteristic of the picture. A special illuminator whose radiation corresponded to that of A or C sources was used as the light source during the colour measurements. A heat-protective light-filter was applied to preclude the influence of the heat rays on the object measured. The illuminator was fastened stiff to the colorimeter in such a way that the optical axes of the colorimeter and the illuminator in the horizontal plane made an angle of about 20°. The colour was measured by the normal. The distance of the object measured was determined by the place of intersection of the optical axes of the colorimeter and the illuminator. These conditions were taken as most reproducible, because when a non-contact registration method is used, the repeatability of the measurements results considerably depends upon the fact how the constancy of the measurement conditions is observed. The colour measurements can be carried out also in the observation and light conditions corresponding 0°/45° or 45°/0°. In this case the illuminator is fastened in a separate special support.

With the help of the colorimeter both the chromaticity co-ordinates x and y and the luminous reflectance Y (%) were determined. The latter was measured relative to a specified white plate made of glass MC 20 placed in the plane of the object measured. Before the measurements the graduation of the colorimeter was carried out using the filters with known chromaticity co-ordinates. The colour measurements of the picture mentioned above showed good repeatability: the chromaticity co-ordinates ±0,002 and the luminous reflectance ±4 %.

We also used the colorimeter to estimate the influence of the stages of the restoration treatment on the colour characteristics of the paint layer of the glue painting on loess plaster from ancient Pendzhikent. The colour measurements were carried out in the course of the experiments on improving the restoration technique using polybutyl methacrylate of low viscosity (6). The experiments were made on samples prepared as paint layers of some present-day pigments on Pendzhikent plaster and on genuine painting fragments having no museum value. In the latter case, in order to measure the colour, the surface areas with the best preserved paint layer were marked with a circle, where colorimeter was focused on. The measurement of the colour characteristics of these areas before treatment and after every stage of treatment were carried out under the same conditions (the size of the diaphragm, sensitivity, distance from the object). Table shows the results of the colour measurements of such samples on areas with the paint layer absent (loess), with a gypsum ground and with a paint layer made in red and yellow ochres, natural ultramarine on gypsum ground. The colours were measured before treatment and after every stage of the treatment chosen as optimal. It consisted in preliminary fixation of paint layer with 2% polyvinyl butyral solution in ethanol - water mixture (7:3) - 2 times, followed by consolidating impregnation with I5-I7% xylene solution of polybutyl methacrylate - 20 times and the final restoring the optical properties of the glue painting surface with the help of methyl ethyl keton - ethanol - water (3:I:I) mixture.

As seen from the Table, fixation does not practically effect the colour of loess, gypsum ground and ultramarine. More appreciable its influence on yellow and red ochres, though it does not exceed +0,004 for the chromaticity co-ordinates and -2% for luminous reflectance. Impregnation with the polymer consideraby diminishes the luminous reflectance and changes markedly the chromaticity co-ordinates. After the lightening operation the luminous reflectance increases but remains 2-3% (in yellow ochre - 7%) lower than before treatment. The chromaticity co-ordinates within the limits of the divergence restored their values in loess, ultramarine

and differs but little from the original in red ochre. The lightening of yellow ochre showed a lesser effect - its colour after treatment may be considered somewhat changed.

That the disinfection treatment with methyl bromide did not effect the colour of present-day water-colours, gouache, some oil paints, as well as fresco fragments from the St George church in Staraya Ladoga - was also shown with the help of the colorimeter. On the ground of the data obtained, the disinfection treatment of the church interior with methyl bromide was carried out.

The authors express their thanks to scientific workers L.R.Mironova (Optical Institute named after S.I.Vavilov) and E.A.Mikolajchuk (Hermitage) for performing a number of measurements for this study.

Table. Change of colour characteristics of Pendzhikent paintings in the course of restoration treatment

Treatment (stage)	Loess (plaster)			Gypsum ground			Dark red ochre on ground			Yellow ochre on ground			Ultramarine on ground		
	x	y	Y, %	x	y	Y, %	x	y	Y, %	x	y	Y, %	x	y	Y, %
Before treatment	0.362	0.358	20.5	0.342	0.35I	34.5	0.378	0.355	I8.2	0.376	0.374	59.9	0.277	0.305	24.9
After fixation	0.362	0.360	I9.7	0.345	0.353	34.8	0.382	0.356	I6.2	0.379	0.378	58.9	0.277	0.305	23.3
After fixation and consolidation	0.366	0.359	9.2	0.352	0.35I	I5.8	0.394	0.355	II.7	0.408	0.383	28.4	0.266	0.293	II.8
After fixation, consolidation and lightening	0.352	0.354	20.6	0.335	0.346	34.5	0.374	0.348	I6.5	0.363	0.363	52.5	0.277	0.303	2I.7

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COMPLEX INVESTIGATION OF TWO-LAYER MURAL PAINTINGS IN THE MAIN TEMPLE OF UDABNO IN DAVID-GAREDJA USING NEW METHODS

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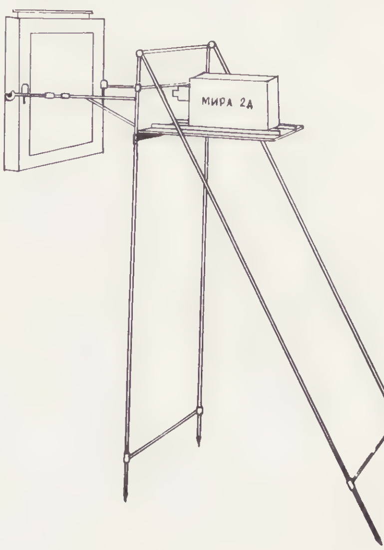
SUMMARY

Two-layer mural paintings in one of temples of the monastery cave complex of David-Garedja, named Udabno, were studied using ultraviolet, infrared and X-rays.
According to literary sources available at present, the cave complex has been known since the first half of the 6th century.
In the cave studied the second layer of paintings was dated to the 13th century whereas there was no agreement on the date of the first one. Some investigators believed that it was painted in the 9th, others in 10th century. Therefore, it was considered important to obtain a clear picture of the first layer. At late Middle Ages the first layer was whitewashed and a new picture was painted on it. At present, due to partial loss of the upper painted and underlying whitewashed layers, the discernment of subjects and an iconographic scheme of the first layer is difficult or, in some cases, impossible.
Studies performed using ultraviolet, infrared rays and X,ray emission analysis revealed a rather clear picture of the first layer, based on which an iconographic scheme could be reconstructed by art critics suggesting that the first layer was painted not later than the end of the 9th century. Besides, a churchwarden inscription was detected in the second layer stating the purpose of the cave: it had thought to be the northern nave but the inscription said that it was a diaconicon.

The David-Garedja monastery complex ocuupies a special place among the cultural monuments of the feudal age in Georgia by both its grandeur and its historical and aesthetic significance. This cave complex is situated 70 km from Tbilisi, the capital of Georgia, along t the slope of the semidesert Garedja mountain ridge. According to literary sources, the historical beginning of the complex is dated to the first half of the 6th century and it was founded by one of the "13 Syrian fathers", David by name. The complex comprises 5 cave monasteries. In one of them, namely Udabno, in the main temple there is a mural painting dedicated to the life cycle of David Garedjeli, an outstanding figure in the Georgian hastory. In the northern nave or side-altar of the main temple, which this cave was believed to ba, investigations of the two-layer paintings by new methods were performed. The researchers date the second layer to the 13th century. On the northern wall this layer bears a hardly visible faded and crumbled inscription which was interpreted as "... this Lukian". As to the date and iconographic scheme of the first layer of the painting, there is difference of opinion.
Over centuries of its existence the monastery complex has been repeatedly ravaged and ruined by Mongols, Tamerlane, Shah Abbas and other other invaders who came to Georgia with fire and sword. As a result, the monasteries suffered a great deal and since the 19th century they have been completely desolated.
All this has certainly affected the state of paintings in this cave which were made on the plaster board. At late Middle Ages the paintings in the northern nave were whitewashed with a very thin layer containing white lead and the walls were newly painted. In the course of time the paint and whitewash layers began to crumble and the remaining hardly traces of the first and the second payers of painting overlap and make interpretation of the subjects of the first layer painting as well as reconstruction of the iconographic scheme difficult or sometimes impossible.
Therefore it was considered important to obtain as clear as possible a picture of the first layer since there was an opinion that the main temple Udabno and its northern nave were painted by one and the same artist in the 10th century, the life cycle of David Garedjeli beginning in the middle nave of the temple and ending in the northern nave, with life events of David Garedjeli painted in accordance with the Life of the Saint David of Garedja as described in a literary source of the 10th century. However, there was also another opinion which was not supported by objective scientific data. In this connection, the present investigation was carried out using ultraviolet, infrared and X-rays. Ultraviolet photography was performed both in reflected beams and using visible luminescence. In the former case technical-purpose photoplates with light filters УФС-2 on the lens were used, the paintings were illuminated by two 1000 W mercury lamps with light filters УФС-6 Visible luminescence excited by near ultraviolet radiation was photographed on Isopanchrom film through yellow light filters ЖС-3 and ЖС-I2. Photography in reflected infrared rays was performed using photoplates "ИК 830" through light filters КС-I9. Halogen lamps were used for illumination. For X-ray emission studies a special installation comprising X-ray pulse apparatus МИРА-2Д with 200 kW tube tension was used. Clear X-ray emission patterns were obtained in all cases when the mural painting contained pigments with a high stomic weight. The size of X-ray emission pictures was 40 x 40 cm. The exposure duration was 3 to 4 minutes.



Schematic drawing of the installation for X-ray emission studies

As the cave monastery Udabno is situated far from the populated area in a place difficult of access, all the equipment needed, including an electric power generating unit, was delivered there by a helicopter. Investigations were carried out in the daytime, with apertures in the cave closed by black curtains.
The research carried out allowed to obtain a rather clear picture of the first layer compositions which has completely changed the existing idea of the iconographic scheme and, correspondingly, the date of the compositions of the first layer.
The data obtained as photographic pictures in infrared, ultraviolet rays and X-ray emission patterns have provided a good evidence that the events of the Life of David Garedjeli, as painted in the northern nave, were not reflected in the available at present version of the Life, written in the first half of the 10th century: the paintings depict lifelike events rather than miracles as described in the Life. The figures of David Garedjeli and his pupil Lukian are painted without haloes. Although the upper layer proved semitransparent to infrared rays and may be partially seen on photographic pictures, one can easily trace the whole cycle of compositions which have no framing and are perceived as continuous strip of paintings beginning on the western wall, northern nave, with the scene of David talking to his pupil Lukian followed by the scene of David praying in front of a cross, the scene of water extraction in a cave with Lukian digging the earth from where water is streaming, and others. The whole cycle ends on the northern wall with the composition of David with stones of gratitude in a sack at the Jerusalem gates behind which the architectural shapes of temples may be seen.

Therefore this study lead to the conclusion that in the revealed ancient iconographic scheme the scenes described in the literary text of the 10th century were absent. Iconographic and stylistic analysis gave the researches grounds to believe that the first layer had been painted before the 10th century since David is not shown as a miracle-worker, as described in the text of the 10th century. The researches suppose that the painting was based on an earlier literary source which was lost and has not come down to our time.
The churchwarden inscription of the second layer in the same cave, which was believed to be the northern nave, was completely illegible. Two or three letters were seen and one could only make a guess at others. In such a state it was read as "... this Lukian". After the inscription was photographed by the method of visible luminescence excited by near ultraviolet rays, it became very clear and proved to consist of three lines of text written in the old Georgian scrip "asomtavrili". Now the inscription was read as "... this diaconicon and a sanctuary were painted". Interpretation of this inscription helped to determine the purpose of this cave which was wrongly taken for the northern nave. By paleographic analysis the inscription was made in the 13th century which confirms the date of the second layer. The microchemical analysis carried out in different points of the compositions indicated the presence of white lead which was also confirmed by X-ray emission analysis.

The scheme of the first and second layer paintings in the northern nave

The scheme of the first layer life cycle (both schemes are compiled by G. Abramishvili)[x]

[x] G. Abramishvili "David Garedjeli life cycle in the Georgian monumental painting", Tbilisi, 1972.

THE INVESTIGATION OF THE METAL EMBROIDERY THREADS OF THE HUNGARIAN CORONATION MANTLE BY SCANNING ELECTRON MICROSCOPE AND PHYSICAL METHODS OF ANALYSIS

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SUMMARY

The Hungarian coronation mantle was probably produced in the 13th century by re-cutting an 11th century chasuble with gold embroidery on it. The technology of the making of the metal threads was investigated in the course of an overall examination prior to conservation-restoration.
The ten samples to be examined were taken both from the original piece and from pieces which have been confirmed as later additions as well as from patches which were sewn to it by way of mending.

In order to study the morphology of the threads, scanning electron microscopic photos were taken while neutron activation analysis was carried out to detect the major and minor elements in the metal itself. The examination of trace elements took place by optical emission spectrometry.

On the basis of the morphology of the threads the following two major groups could be distinguished: 1 Metal strips produced from a piece of wire by hammering or rolling spun round a silk core; 2 Metal strips cut off from metal plates spun round a silk core. Within each group further characteristics could be observed reflecting the advancement of the technology.
On the basis of the material tests also two groups could be distinguished: 1 Gold threads; 2 Gilded silver threads. Quite naturally within each group further sub-groups could be established according to the quantitative and qualitative analysis.

Thus the complementary morphological and analytical tests not only revealed bits of information concerning the techniques of manufacturing but also made it possible to identify and range certain pieces /e.g. patches/ with parts whose chronology had already been verified.

INTRODUCTION

The Hungarian coronation mantle is the sole item that has survived from among the coronation vestments.
The bell-shaped chasuble from which the mantle was transformed probably in the 13th century "was ordered to be made and given to the church of St. Mary...by King Stephen and Queen Gisela in the lo31st year of Christ's incarnation..." as the embroidered inscription says /1/.
The object that may be considered unique even by Europaen standards, arrived home in 1978 together with the rest of the coronation regalia.

The mantle consists of three main parts: the mantle itself, the strap and the collar. There are also two tassels hanging on braids.

The object richly ornamented by gold embroidery has been mended several times in the course of history and almost each century left its mark upon it /2/. In the course of the investigation still under way and aiming at conserving the object, a thorough examination of the metal threads was also carried out.
The aim of the tests was the studying of how the metal embroidery threads of different periods were produced. Over and above that with the relevant information in their possession art historians may be able to provide answers in connection with the history of the mantle to problems which have been unsolved till now.
For the purposes of the examination very few samples could be taken from the 19th century and the previous braid from the two kinds of thread of the collar /used for filigree and Anlegetechnik/ - the latter probably originating from the 13th century for it was considered that the embroidery that is in good shape should not be undone. The same applied to three of the patches on the mantle which were added by way of mending. /In course of the investigation eight more patches were detected./ The length of the samples was lo-15 mm in all and they weighed 5-6 mg only. Some more samples could be taken from the mantle originating from the 11th century, from the strap and the 19th century tassel.

THE MORPHOLOGICAL EXAMINATION OF THE THREADS

When examining the ten samples by microscope it was found that all the metal threads belong to the group where a fine /about lo μ/ thin /about o.2-o.6 mm/ metal strip was spun round a kind of textile core /the core was usually silk but in many cases linen or cotton yarn was found/ /3/.

In order to establish the dimensions of the threads as well as for further morphological observations, scanning electron microscopic analysis followed. At high amplification /magnificed about 2oo-3oo times/ it was found that two groups are discernible which differ in the manner of the making of the metal threads spun round the core:

1 Metal strips produced from a piece of wire by hammering or rolling. Here belong the samples from the mantle, the strap, the collar and Patch 2 and 3.
2 Metal strips cut off from metal plates. Here belongs the thread sample taken from Patch 1.

It cannot be decided which heading the thread of the braid of earlier origin should fall under, but probably it was also produced from wire. Similarly the ranging of the two 19th century samples is dubious.

1 Metal strips produced by hammering or rolling

In the case of these threads, the width is varying, the edge is uneven /Fig. 1/ sometimes /obviously owing to the composition of the metal/ there are perpendicular cracks /Fig. 2/. The uneven edge is occasionally bent backwards /Fig. 3/.
As far as our knowledge goes, there is no written evidence concerning the production of metal embroidery threads in the given historical period. Since, however, the technique of wire drawing has been known since the 5th-7th cc. /4/ it cannot be

excluded that such a procedure was applied. All the more so since by this method much longer strips could be produced than by cutting relatively small pieces of gold plates into strips.

In order to verify the above assumption, a piece of gold wire with higher silver content was made into a strip by hammering and spun round silk. The electron microscopic photos render our hypothesis probable /Fig. 4/.

In three instances /the mantle, the strap and Patch 3/ it was possible to observe the joining of the metal threads, too. As for the strap, the end of the strip and the end of the next metal strip were joined uninterruptedly. In the other two cases double twisting may be observed.

The filigree embroidery thread of the collar was produced by an interesting technique, i.e. the thread was hammered and was once more spun round another silk thread in order to obtain a thicker embroidery thread.

2 Strips cut off from metal plates
Threads produced in this manner will show a characteristic cutting face along the edges /Fig. 5 and 6/.
The production of metal embroidery threads by the above means is mentioned among others in the Bible /5/ and by Presbyter Theophilus /6/.

Figure 1 Embroidery thread of the mantle x78, scale bar=loo μm

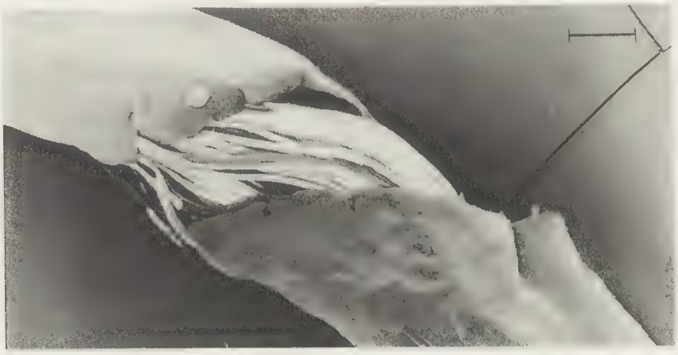

Figure 2 Thread from the mantle probably meant for mending x78, scale bar=loo μm

Figure 3 Detail of the enlarged edge of the metal thread of Patch 2 x6oo, scale bar=lo μm

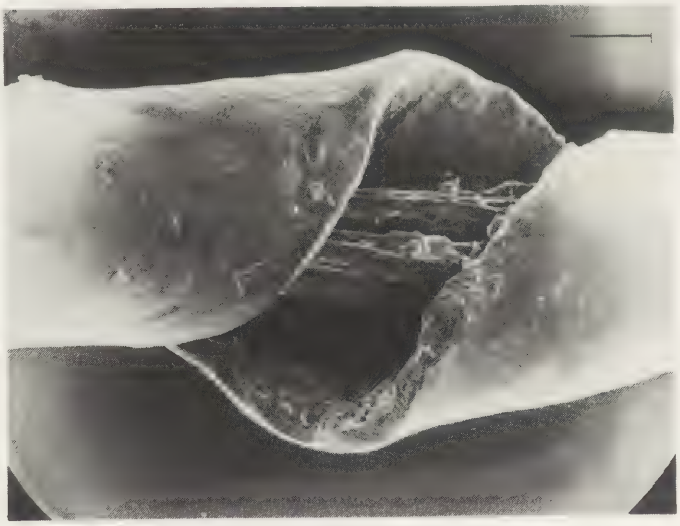

Figure 4 Enlarged section of the embroidery thread of our own making x2oo, scale bar=5o μm

Figure 5 Embroidery thread of Patch 1 x78, scale bar=loo μm

Figure 6 Enlarged section of the thread in Figure 5 x3oo, scale bar=25 μm

MATERIAL TESTS

By way of visual and microscopic examination nine of the ten samples seemed to be gold, on the braid of earlier origin the black corrosion product of silver could be found, but even here the gold was shining through in some places.
In order to establish the composition of the alloys the metal threads were made of, neutron activation analysis was used, while for the detection of trace elements optical emission spectrometry was applied. On the basis of the analytical results the threads could be divided into two groups:
1 Gold alloys: the threads of the mantle, the strap, the collar and the patches.
2 Gilded silver: the threads of the braid of earlier origin and the two 19th century samples /braid and tassel/.

1 Gold alloys
The results of the neutron activation analysis for the seven gold alloy samples are given in Table 1

Table 1

Sample \ Component	Au	Ag	Cu
strap	99.39	0.49	0.04
Patch 2	99.25	0.66	0.09
Patch 1	98.40	1.20	0,40
mantle	97.60	2.00	0.40
Patch 3	96.59	2.45	0.40
collar /Anlegen/	90.20	7.10	2.60
collar /filigree/	88.70	9.10	2.10

According to the above results the threads made of gold alloys may be divided into three further sub-groups.
1.1 Very fine gold, containing only o,5-1,o % alloying addition /the strap, Patch 1 and 2/;
1.2 Fine gold, containing 2.5-3.5 % alloying addition /the mantle, Patch 3/;
1.3 Gold containing more /about lo %/ alloying addition /the threads of the collar.

The result of trace element test: aluminium, magnesium, silicium and iron was found in each case. This may be the result of dirt taken up from the environment but could point to inclusions, too. Tin was found in the samples of group 1.1 and 1.2 and lead occured in group 1.3. As for tin and lead, it should be noted that the concentration of both elements was round the detection limit which means that if bigger amount of samples were taken they could be perhaps traced in each sample. Mercury and platinum was found in two samples from the mantle. The trace element tests call for further investigations.

2 Gilded silver
The results of the neutron activation analysis for the three gilded silver samples are given in Table 2

Table 2

Sample \ Component	Au	Ag	Cu
braid /earlier/	0.73	54.0	45.2
19th century braid	2.80	96.9	0.3
19th century tassel	2.90	96.5	0.5

On the basis of the results it can be pointed out that the composition of the silver copper alloy of the braid of earlier origin is completely different from the two 19th century samples which in turn are of the same composition.

Results of trace element tests: aluminium, magnesium and silicium /in all three samples/ tin /in the two 19th century samples in concentration round the detection limit/; lead /in the older braid somewhat higher proportion, in the two 19th century samples in concentration round the detection limit/. /Iron could not be found in any of the samples./

CONCLUSION

The joint evaluation of morphological and analytical results led us to the following conclusions:
From among the threads made of gold alloys, two of the very fine gold threads /the strap and Patch 2/ had been made by the same method, both having been hammered from wire. The metal strip of Patch 1 had been produced by different means, i.e. by cutting it off from a metal plate /its silver content is also higher than that of the other two/.
The fine gold threads of group 1.2 /from the mantle and Patch 2/ are the same both as regards their making and the joining of the metal strips.
In group 1.3 - samples containing more alloying addition - threads /from the collar/ are slightly different as regards their composition but both were made from wire by hammering.

As for the gilded silver threads, the composition of the two 19th century samples /braid, tassel/ is the same. Since both sides of the metal strips are gilded but the gold layers are not to be seen on the edges, it may be assumed that gilding took place after it had been shaped. The edge of the braid of earlier origin is bent upwards, presumably during spinning some kind of a thread guide was used and this brought about the deformation.

AKNOWLEDGEMENTS

The author is grateful to Ms E. Gondár for the scanning elecron micrographs and to Ms M. Balla and Dr. J. Bérczi for neutron activation measurements.

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DENDROCHRONOLOGICAL STUDIES ON PANELS BY JEAN FOUQUET (1415/20 - 1477/81)

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Summary

Dendrochronology can be used for dating wooden objects of history and art. Recently it was possible to establish a new chronology for the period from 1440 to 1248 applied to determine the felling date of trees used for panels of Jean Fouquet (1415/20 - 1477/81, Tours).

Introduction

The dendrochronological method is a very effective tool for determining the age of wooden objects. By determining the felling date of the tree which provided the wood for a particular panel a "terminus post quem" i.e. the point in time after which the painting could have been created can be given. The precondition for a dendrochronological analysis is a reliable reference chronology for the regions in question. It is possible to date the age of wooden panels used for paintings created by Dutch, English, Flemish and German artists for the period between 1400 and 1800 AD (Bauch, Eckstein (1981), Bauch, Eckstein, Brauner (1978), Eckstein, Bauch (1974), Fletcher (1976, 1980), Klein (1981, 1983), Klein, Bauch (1983).

For the processing of the dendrochronological data obtained from oak panels used by Fouquet, i.e., the determination of the felling date, first a new master chronology for the region where Fouquet had been working had to be established.

Dendrochronological dating of the oak panels by Fouquet

Since the basic facts and the methodical concept of the dating procedure have been described in many publications only the special aspects relating to the panels will be explained and they will be supplemented by the results for the investigated paintings.

Oak panels were usually cut from the tree trunk with an approximately radial orientation. As the sapwood is light coloured and perishable and may contain growth rings of 20 ± 5 years depending on the age of the tree, the accuracy of dating will depend on exactly how the panels were prepared. Those which contain a few sapwood rings allow a determination of the felling date with an accuracy of ± 5 years. If no sapwood is present the felling date can only be approximated by adding to the latest measured growth ring, a minimum of 15 sapwood rings. The possible error in the felling date is indicated by a term such as 20 $\pm^{x}_{5}$, where "20 - 5" accounts for the number of sapwood that might be missing, while the "x" stands for an unknown number of missing heartwood rings.

After these preliminary remarks more details of the 5 paintings of the œuvre attributed to J. Fouquet are described.

The growth ring curves of 15 measured oak boards could be combined with each other and a relative chronology has been derived. A cross dating of this mean curve with the master chronologies of Southern and Western-Germany allowed an absolute dating for the period from 1440 to 1248 and the attribution of the single boards (Fig. 1).

It is obvious that the boards II and III of the panel "Chevalier" and board I of the panel "The virgin" came from the same tree while the boards I (Chevalier) and II (The virgin) originate from another tree (Fig. 2). The last measured growth ring in the two panels grew in the year 1431 and the felling date of the tree has been determined as 1451 $\pm^{x}_{5}$.

The painting "Guillaume Jouvenel des Ursins" consists of 5 boards. The growth rings have been dated and cover the period from 1440 to 1291. The felling date for the trees from which the boards had been cut has been determined as the year 1460 $\pm^{x}_{5}$.

The panel for the painting "Charles VII" has been assembled from 4 boards joined together in the old frame. So far it was only possible to measure the right board directly on the back side. The last measured growth ring of this board grew in the year 1411. Because 1 or 2 centimeters of the board in the direction of the sapwood are under the frame and therefore not measurable, a felling date cannot be given as yet.

The painting "Jester Gonella" some times attributed to Fouquet, is made of one board with 171 growth rings dated between 1411 and 1241. A felling date with 1431 $\pm^{x}_{5}$ can be derived. The growth ring sequence of this tree is very different from the other ring series and after cross dating a provenance from the Netherlands must be concluded.

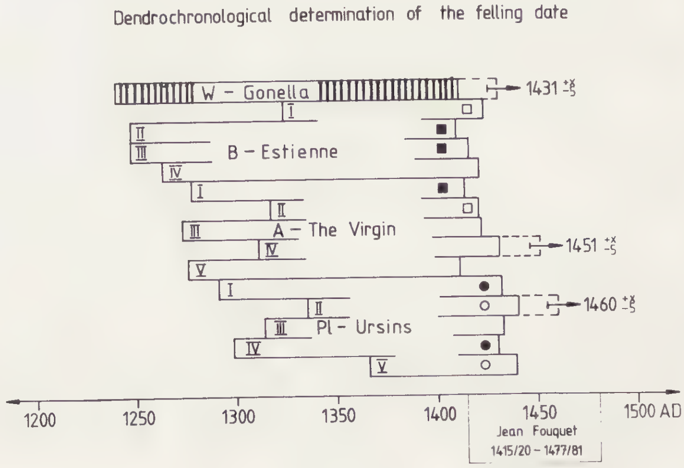

Fig. 1: Dendrochronological dating of oak panels attributed to J. Fouquet and his circle. ▭ - heartwood; ⟼ - earliest possible felling date; ▭ - origin: France; ▥ - origin: Netherlands. A - Koninklijk Museum voor Schone Kunsten, Antwerp; B - Gemäldegalerie, Berlin-Dahlem; PL - Louvre, Paris; W - Kunsthistorisches Museum, Vienna.

Fig. 2 J. Fouquet (1415/20-1477/81): "Estienne Chevalier" Gemäldegalerie Berlin-Dahlem and "The Virgin with the Child" Koninklijk Museum voor Schone Kunsten, Antwerp; construction of the two panels from different boards; □, ■ - symbols for the boards from same tree; i - towards the pith; o - towards the bark.

Conclusions

The dendrochronological analysis of the oak panels of Jean Fouquet allows the determination of the year when the last measured tree ring on the board had been growing. Besides the felling date also the time the wood had been stored for drying and conditioning prior to its use for painting has to be considered. Present studies on Flemish panels indicate a storage time of 10 to 15 years (Klein 1983). Under the assumption of the minimum of 15 sapwood rings and 10 years for the storage time the following years for the creation of the paintings can be derived:

"Estienne Chevalier" and "The Virgin with the child": from 1456 onwards. "Guillaume Jouvenel des Ursins": from 1465 onwards. "Jester Gonella": from 1436 onwards. These data can serve to the art-historian in support of his final decision.

Aknowledgements

I would like to express my gratitude to the Gemäldegalerie Berlin-Dahlem; Koninklijk Museum voor Schone Kunsten, Antwerp; Musée de Louvre, Paris and Kunsthistorisches Museum Vienna for making available the paintings by Jean Fouquet for this investigation.

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IMPURITIES IN WHITE LEAD AND THE METALLURGY OF LEAD

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SUMMARY

To all appearances, cupellation as a method of extracting silver from rough lead was in a quite limited use or not used at all in Europe up to the middle of XIX century. That is why in the samples of white lead from pictures of old masters the microspectral analysis made with the help of a laser microprobe reveals all the impurities characteristic for rough lead. In particular, the silver content in the white lead of old pictures is usually in the range of 0,01 - 1.00%.
With the introducing in 1833 the process of Pattinson and in 1850 that of Parkes the silver content in white lead decreases up to 0.01-0.0001%, and the zinc impurity content, as a consequence of Parkes process, can reach 1-2%.

White lead is an artificial paint which has been used in painting ever since the antiquity. The methods of the white lead preparation have been repeatedly described in literature. Depending on the manufacture technique, the paint composition can be expressed by the formulae: $PbCO_3$, $2PbCO_3 \cdot Pb(OH)_2$, $3PbCO_3 \cdot Pb(OH)_2$, $5PbCO_3 \cdot Pb(OH)_2 - PbO$.

Being an artificial lead paint, white lead carries in itself the information of the development level of the lead meallurgy which, in the first place, manifests itself both in the presence and the amount of the impurities concentrations.

The so called "rough" lead (German "Werkblei") always contains a number of ore impurities: silver, copper, zinc, tin and others. The compositions of the present-day rough lead of different works are given in Table 1.

In the current metallurgical process use is made of various methods for extracting the impurities from lead. This, first of all, refers to the most scarce metal - silver.

Cupellation - the process of the melted rough lead oxidation to PbO - appears to be the oldest method for extracting silver; silver having lesser oxygen affinity is not oxidized and it occumulates as metal at the bottom of the bath-cupel.
The production of silver however in 1800 was about 870 t, and lead - 34000 t, that is, the amount of silver produced was about 4% of the quantity of the lead. This fact allows a conclusion to be made (see the silver content in rough lead, Table 1) that silver, in the main, was smelted from rich silver ores (argentite, kerargyrite, pyrargyrite and others). To suppose all the lead produced to be the reduced by - product of silver-extraction seems unreal. The existance of silver-independent lead production is supported by extensive studies of white lead with the help of a laser microprobe more than once described in literature. Here we shall only point out that the analysis locality in most cases was in the range of 50-100 μm the laser pulse longitude (free generation mode) - 500 μsec., the exciting charge delay relative to the laser ignition pulse - 200 μsec., the charge parameters: U = 7,8 kV, C = 1.0 μF , L = 100 μH.

Table 1. The composition of rough lead from different works, %

Works Country	Pb	Cu	As	Sb	Bi	Ag
Chimkent, USSR	92-94	1.8-2,2	0.4-0.6	0.3-0.5	0.15-0.20	0.10-0.15
Ust-Kamenogorsky, USSR	90-91	2.0-5.0	1.0-2.2	1.0-1.5	0.05-0.07	0.12-0.16
Electrotsink, USSR	93-97	0.8-1.3	0.3-0.7	0.8-1.2	0.1-0.2	0.1-0.2
Port-Pirie, Australia	97-98	0.8-1.2	0.15-0.2	0.3-0.6	0.003	0.146
Trail, Canada	96-98	-	0.2-0.5	0.6-0.7	0.12	0.12
Bunker-Hill, USA	94-96	1,8-2,3	0.5-1.0	1.5-2.0	0.02	0.5
San-Gavino,Italy	95-97	1.5-2.0	0.1-0.3	1.0-1.5	0.07	0.08
Plovdiv, Bulgaria	95-97	1.0-3.0	0.1-0.3	0.2-0.4	0.03-0.04	0.08-0.13
Pshibram, Czechoslovakia	90-92	0.8-1.0	0.5-0.8	5.0-6.0	-	0.6

As an example, in Table 2 given are some data on the content of copper and silver impurities in white lead of some Titian paintings from the Hermitage collection. The data reflect exactly the order of the concentration of the value measured.

Table 2. Copper and silver impurities in white lead from Titian paintings from the Hermitage collection

Inv.N	Subject	Ag,%	Cu,%
71	Portrait of a Young Woman	0.05	1.0
191	St.Sabastian	0.05	1.0
121	Danaya	0.1	0.1
118	Madonna and Child with St.Mary Magdalene	0.01	0.1

Some amounts of copper and silver impurities concentrations are to be met without any exceptions in all pictures investigated up to now in the Hermitage laboratory. The values found is a decisive indication in our examination work for detecting imitations and fakes. The largest amount of silver concentration in white lead so far registered is about 1.0% (Clouet F.? Portrait of Duke Alansone, N 1255).

It should be noted that in all known to us works on neutronactivation analysis of white lead the estimate of the values of microimpurities concentrations is 1-2 orders too low.

Thus, according to G.Kühn, the silver and copper impurities content in white lead of XVII century for Netherlands was on the average correspondingly 0.006% and 0.0064%. Concentrations low as these were to have indicated the fact that purification of lead was then on a rather high level equal to that of some present-day grades (for example, home lead grade C3C). Thus the question of white lead production from rough lead may be proposed as a possible topic for discussion during the working meeting.
Extracting silver from all the bulk of the lead produced became customary only after the Pattinson (I833) and, especially, the Parkes (I850) metallurgical processes were introduced into manufacture. X/.
X/ The Pattinson process is based on the fact that the lead and silver alloy has the lowest melting point (304°C) when the silver concentration in lead is 2.3%. That is why, if rough lead is heated up to the temperature somewhat higher than 304°, there will exist in the form of a melt only the lead containing about 2.3% of silver, the rest of the lead (desilverized) becomes hard. The melted part is poured out and subjected to cupellation for extracting the silver. The process was named after H.L. Pattinson who introdused it in England in I833. Pattinsonising is possible only in the absence in rough lead of large amounts of copper, arsenic, antimony and, practically, is more complicated than the Parkes process. At present it is used only in cases when rough lead contains bismuth.
The Parkes process is a method of extracting silver from melted lead with the help of some addition of zinc melt. Due to the formation of some intermetallic compounds, practically all silver contained in the lead concentrates in the zinc layer which, because of its lesser density, is on the melt surface. This layer is poured out and the silver is extracted from it after distillation of the zinc. The lead, desilverized by the Parkes method, with a high concentration of zinc, was put in XIX century directly on the market. The process is named after an English technician Parkes who was the first to use it for production in England in I850.
That is why, since, approximately, the middle of XIX century the silver content in white lead has been approaching the present day level, amounting to 0.0I-0.000I%. A remarkable thing which resulted directly from the application of the Parkes process is also the appearance of zinc impurity in white lead _0.5-2.5%.
Numerous attempts have been made to account for the appearance of zinc. Some authors think that this impurity was caused by the firms-manufacturers who deliberately added some cheaper white- the zinc one to white lead; others point out that zinc could be introduced into white lead in the course of grinding from the millstones contaminated with the remnants of zinc white left from the preceding grinding. The first point of view is not confirmed by the zinc concentration value, being too small. The latter, on the contrary, is not confirmed by the value, being too large.
In conclusion it should be mentioned that the production of many paints was very closely connected with the metallurgical process. Thus, recently, the examination of the yellow paint from the portrait of Metternich presumably a work of Lawrence,showed that it contains as basic elements lead, tin, antimony, that is, the paint is a mixture of lead-tin yellow and Naples yellow. As is known, yellow slag of such composition is obtained at the first stages of lead cupellation. Hence, the paint may be assumed to be of a direct metallurgical production.
This conclusion finds an indirect support in the fact that the white lead sample from the above picture contained neither silver nor copper in amounts detectable with the laser microprobe, and the yellow paint contained such impurities in quantities typical for rough lead.
The appearance in XIX century a so called Cremnitz white (the white leade made of litharge) may well demonstrate another example of usage in paints production the by-product of cupellation - litharge.
The identification we carried out of the so-called "bell earth" found in the fresco pain in XV century Pskov is one more example of this connection with metallurgical process. The paint has a violet colour and is of a rather complex copper based composition. Judging from the latter, the paint may have bee the inner part of a clay mould used in casting the copper article.

LABORATOIRE ET SERVICE DE RESTAURATION:
COLLABORATION A PROPOS DE LA CHARITE
D'ANDREA DEL SARTO

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RESUME

La Charité d'Andréa Del Sarto (Musée du Louvre) restauré en 1980-81 (1) a été l'objet d'une collaboration scientifique entre laboratoire et Service de Restauration. Deux aspects ont été retenus pour cette communication:

- le problème complexe du nettoyage des bleus du ciel
- une tentative d'explication de la méthode de transposition de Robert Picault en 1750.

L'historique des restaurations subies par ce tableau commence par la transposition spectaculaire de 1750 où Picault remplace le support original sans le détruire. Une étude du tableau à l'aide des diverses méthodes scientifiques est faite, suivie de l'exposé du traitement de purification du ciel. Tout au long de ce traitement, il est montré que la collaboration avec le Laboratoire de Recherche des Musées de France a été capitale pour la réussite du travail. Enfin la confrontation de quelques textes anciens et des réalités chimiques de 1750, par un chimiste du CNRS, familier avec la connaissance technique de tableaux a permis d'émettre une hypothèse sur le "secret" de Picault.

INTRODUCTION

Le cas de la Charité d'Andréa Del Sarto, récemment restaurée, est à la fois très important dans l'histoire de la restauration et exemplaire par les résultats de cette collaboration dont deux aspects particuliers ont été retenus pour cette communication:

- le problème complexe du nettoyage des bleus ciel.
- une tentative d'explication de la méthode de transposition de R.Picault en 1750.

I - Historique des restaurations successives.

Le tableau dont l'état se dégradait "la planche sur laquelle il étoit peint étoit entièrement vermoulue et il seroit tombé en poussière" (sic) (2) disent les textes de l'époque, fut en 1750 le premier à être transposé officiellement. Mr. de Tourneham, Directeur des Bâtiments du Roi le confia à un artisan Robert Picault qui avait mis au point une méthode de transposition sur un nouveau support, des peintures exécutées, soit sur plâtre, soit sur bois, soit sur toile.

Le tableau transposé de bois sur toile fut exposé au Luxembourg avec, "à côte la planche sur laquelle il avait été peint" (3). L'emerveillement fut général mais Picault, bien que comblé d'honneurs et d'argent ne voulut jamais révéler son "secret".

La méthode "classique" de transposition, déjà pratiquée par les rentoileurs contemporains de Picault, et toujours utilisée actuellement consiste à détruire le support original et à le remplacer par un autre, afin d'atteindre par le revers, la préparation originale désagrégée et la régénérer ou la remplacer afin de rétablir l'adhérence compromise entre support et couche picturale. La méthode de Picault était différente car elle ne détruisait pas le support original. Une restauration picturale (de Picault et Colins) suivit la transposition de 1750 (4). Puis eurent lieu : en 1780 une reprise de transposition ou un simple changement de toile par le rentoileur J.L. Hacquin (5) en 1789-90 une restauration picturale par Martin qui a "nettoyé et reccordé une multitude de trous" (6) en 1803 une "mise sur deux toiles" par F.T. Hacquin (ce qui signifie reprise de transposition (7) et une restauration picturale par Hooghstoel (8) enfin en 1845 une reprise de transposition par Landry (9) et une restauration picturale par Ribet (10) jugée par Villot, alors Conservateur des Peintures du Louvre.

Les archives n'ont livré ensuite aucune autre intervention importante. L'adhérence de la couche picturale au support était encore suffisamment bonne en 1980 pour qu'il n'ait pas été nécessaire de la consolider.

II - Etude du tableau en 1980-81 avant la nouvelle restauration.

Qu'allait-on trouver sous les repeints de 1750, de 1789-90 de 1803 et de 1846-47, puisque les usages des restaurateurs de ces époques consistaient à ne pas enlever la totalité des repeints de leurs prédécesseurs, se contentant de les amincir et de les raccorder avec les zones originales? Parmi les nombreux problémes posés par la Charité, l'état préoccupant du ciel a joué un rôle primordial. L'examen à l'oeil nu apportait peu d'informations sur l'état réel de l'original car il était recouvert de très abondants surpeints et de plusieurs couches de vernis épais et jaunes. L'état de surface était particulièrement inquiétant puisqu'inégal, comprenant de larges zones dépourvues de craquelures. La partie droite semblait cahotique et à première vue on pouvait craindre de ne trouver que peu d'original intact sous ce magma.

Ce problème a longuement été évoqué avant même que la décision de procéder à la restauration ait été prise. Les responsables de l'oeuvre ont demandé au restaurateur de faire un certain nombre de sondages et de donner ensuite son avis sur la possibilité d'une restauration.

Etablissement du dossier préliminaire :

Ce dossier a été établi en vue d'évaluer avec un maximum de précision la proportion d'original intact qu'une restauration ferait découvrir et la qualité de sa conservation sous les couches d'ajouts successifs. Il aurait été impossible d'établir un tel bilan sans le secours des moyens d'investigation scientifiques mis à notre disposition par le Laboratoire de Recherche des Musées de France:

- les photographies sous éclairage tangentiel ont souligné l'état de surface et ont localisé les surépaisseurs et les dépressions.
- la photographie de fluorescence d'ultra violet n'a pas apporté d'information nouvelle à cause de l'épaisseur des vernis mais elle en a souligné l'abondance.
- la photographie sous rayonnement infra rouge a démontré l'amplitude des surpeints profonds. Elle a prouvé que les zones sans craquelures étaient d'épais surpeints largement étendus et

correspondant aux surépaisseurs notées sur les photographies sous éclairage tangentiel.

L'ensemble de ces documents a apporté des précisions interessantes sur l'état de l'oeuvre ; les radiographies ont permis d'évaluer avec encore plus de précision l'importance et la configuration réelle des lacunes de l'original. A partir de l'image radiographique de cette zone du ciel, il a été possible de procéder à des sondages dans les endroits les plus représentatifs et d'apprécier d'avance la proportion d'original qu'on pouvait espérer découvrir après purification. Cette proportion étant jugée suffisamment importante et la qualité de la matière picturale dégagée satisfaisante, la décision de procéder à la restauration de l'oeuvre a été prise. En raison de l'abondance des surpeints et des couches successives de vernis altérés, l'ensemble des responsables de l'oeuvre a opté, sur proposition du restaurateur, pour un traitement de purification totale, le principe d'un allègement étant inaplicable dans ce cas.

III - Traitement de purification

Le traitement a été exécuté par zones successives correspondant aux clichés radiographiques. En ayant en permanence à côté de l'oeuvre les clichés donnant une image de ce qui serait découvert, le travail a été considérablement facilité.

Les vernis et surpeints des restaurations les plus récentes ont été éliminés en premier sans difficultés particulières pour l'identification ou la réalisation matérielle du traitement. L'abondance des vernis et des surpeints, souvent mêlés les uns aux autres, donnaient au tableau cette apparence glaupe et imprécise. Sous cette couche mêlée de vernis et de surpeints se trouvait une couche grisâtre (réagissant aux solvants comme une couche protéinique), quelques restes d'un vernis très sombre et de larges zones de deux types:
Certaines zones avaient un aspect lisse, sans craquelures, de couleur grise bleuâtre. Elles étaient en surépaisseur par rapport aux autres zones et correspondaient aux surpeints très importants indiqués par les photographies sous rayonnement infra rough et sous éclairage tangentiel. D'autres zones présentaient une surface craquelée, affectée des mêmes fissurations que l'original, mais leur couleur légèrement plus violacée les rendaient suspectes.

Une première série de prélèvement a été effectuée par le Laboratoire de Recherche des Musées de France à la demande du restaurateur qui, se trouvant devant une surface picturale cahotique, ne pouvait poursuivre son traitement.

Les conclusions de rapport et l'observation des coupes (particulièrement les coupes I et VII (11) ont apporté de précieux éclaircissements:

- la stratigraphie de la couche picturale de l'original a pu être précisée: elle est constituée de deux couches de bleu, la plus profonde colorée par du carbonate de cuivre et la couche superficielle par du lapis lazzuli. Ces deux couches sont usées et désorganisées par les transpositions, ce qui explique l'état cahotique de la matière picturale.
- la couche grisâtre est une matière protéinique; sa présence conjointe à celle d'un vernis confirme l'existence d'une restauration très ancienne.
- les zones grisâtres et lisses sont des surpeints puisque superposés à la couche protéinique et au vernis. Leur composition est à base de céruse et bleu au cuivre plus finement broyé que dans la couche originale.

Ces surpeints épais et très résistants ont été éliminés mécaniquement, sous binoculaires. Ils recouvraient les grandes lacunes du ciel en débordant très largement sur les zones usées et fragmentaires qui entouraient ces lacunes. La couche protéinique et les restes de vernis ont été éliminés sans difficulté.

Le problème des zones présentant un aspect craquelé mais d'une tonalité légèrement différent de l'original restait à résoudre: de petits sondages pratiqués sous binoculaires ont démontré que sous un glacis très mince la matière sous jacente est grise. Le glacis donne l'impression d'un surpeint mais sa coloration si proche du lapis luzzuli impose de supprimer ce matériau sous contrôle scientifique:

Une deuxième série de prélèvements a été demandée au Laboratoire (12) reprenant la description de la stratigraphie de l'original, l'analyse confirme la présence des deux couches: blanc de plomb et azurite puis blanc de plomb et lapis lazzuli. Le glacis violacé est bien du lapis lazzuli mais broyé plus finement que dans l'original et en proportion plus forte par rapport au blanc de plomb. D'autre part la coupe montre la présence de vernis entre l'original et ce glacis, ce qui l'identifie comme surpeint. Des sondages plus importants ont alors été opérés. Les zones recouvertes de ce type de glacis étaient généralement constituées de matière originale plus ou moins décolorée et souvent située au voisinage des grandes lacunes ou dans des zones très dégradées. Ces surpeints ont été prudemment éliminés lorsqu'ils débordaient sur des zones d'original dont la dégradation n'était pas trop importante mais sur les zones devenues tout à fait grises, ils ont été conservés en raison de leur ancienneté, de la qualité du pigment et de leur fonction remplie de manière assez satisfaisante.

Le traitement de purification de la Charité, particulièrement celui de la zone du ciel, a donc pu être mené en toute sécurité grâce à l'assistance des documents scientifiques établis par le Laboratoire de Recherche des Musées de France. Pendant ce traitement, l'état réel de la couche picturale originale a été découvert. Les traumatismes subis au cours des âges, particulièrement lors de la première et mystérieuse transposition de R. Picault, ont été découverts: la couche picturale a été usée par la face ainsi que par le revers, elle a été désorganisée - "sa stratigraphie étant par endroits très complexe, des fragments de matière brisée étant juxtaposées ou superposés de façon cahotique" - (13).

Outre ces traumatismes mécaniques, elle a subi des agressions chimiques car les plages décolorées sont le témoin d'une dégradation du lapis lazzuli. Serait-il possible de trouver dans le "secret" de R. Picault une explication à ces divers phénomènes?

IV - Essai d'explication scientifique de la méthode de transposition de R. Picault.

La transposition non destructrice du support original, faite par Picault, était-elle réalisable ou était-elle une supercherie?

La confrontation des quelques textes anciens existant sur ce sujet, avec les possibilités chimiques de 1750 ont permis à Jean Petit (Directeur de Laboratoire de Recherches au CNRS) de donner une explication, qui a été

confirmée au cours du nettoyage.

Dans le journal de Trévoux de 1751 on lit: "M. Picault travaille longtems (sic) avant que d'enlever un tableau de dessus un fond. Ce précieux épiderme est tellement inhérent sur la matière qui l'a reçu d'abord que le feu seul est un grand feu accompagné des liqueurs qui sont le secret peut à peine consommer l'opération... Le Sieur Picault, détrempe le tableau c'est-à-dire l'impression du peintre et l'ordonnance totale de l'ouvrage au point de lever ensuite toute cette peinture comme on lève une estampe en la décollant tout demeure lié, tout se tient, tout se transporte en même tems (sic) sur un nouveau fond ... qui reçoit promptement ce qui a été séparé de l'ancien. Il est enduit d'une forte composition qu'on appelle marouflе" (14).

Picault justifie lui-même en ces termes, les sommes importantes qu'il demandait: "L'ouvrier est presque toujours en danger de périr, forcé de respirer les vapeurs sulfureuses et nitreuses qu'exhalent continuellement les matières employées dans ces opérations" (15) et dans son mémoire de paiement il précise: "ouvrage de près de 9 mois ten (sic) de jour que de nhuis (sic)" (16).

Voici comment en résumant on peut, avec J. Petit, imaginer le déroulement de l'opération (17). R. Picault devait faire pénétrer par la face arrière du tableau, à travers le panneau de bois, des vapeurs d'acide nitrique provoquant une modification profonde des substances organiques et minérales constituant encollage, préparation, imprimatura et entraînant une désolidarisation entre support et couche picturale. Mais l'agressivité de l'acide nitrique est telle à l'égard des constituants du tableau, que Picault ne devait pas couvrir la peinture pour surveiller sans arrêt, nuit et jour, l'évolution du processus destructeur afin de l'arrêter avant qu'il atteigne le revers des couches de couleur; la préparation et l'imprimatura ayant été détruites.

"Il est assez difficile d'imaginer comment Picault pouvait limiter l'action de l'acide à la couche juste au contact du bois sans diffusion dans les couches colorées; les trois constitutifs du bleu: azurite, lapis lazzuli, blanc de plomb n'y auraient pas résisté: ce qui n'est pas observé. On remarque cependant dans le ciel deux atteintes chimiques: des auréoles verdâtres dues à une certaine diffusion des sels solubles de cuivre, à partir de l'azurite et des zones de décoloration du lapis lazzuli devenu un peu gris. Le bois, très vermoulu, surtout dans la planche de droite a laissé passer plus facilement les vapeurs d'acide provoquant une dégradation plus accentuée que dans les autres zones du tableau" (J. Petit). Ces explications, qui confirment les conclusions du Laboratoire de Recherche des Musées de France, ont été capitales pour la compréhension de l'état des bleus du ciel. De plus, un prélèvement de la marouflе étendue par Picault au dos des couches colorées et conservée en grande partie malgré les interventions successives, a montré (à Jean Petit) qu'il s'agissait d'un résinate de calcium, dans lequel une gaze était noyée.

"Le pouvoir adhésif de cette marouflе n'est pas durable, car avec le temps il y a durcissement, et fendillement (cette perte de souplesse a provoqué des microfissurations généralisées des couches colorées) et oxydation de la partie résine (ce qui a amené le système à devenir pulvérulent)" J. Petit. On comprend mieux après cette analyse à la fois l'état de rupture de la matière picturale originale en de multiples lignes de cassures et le peu de durée de l'intervention de Picault puisqu'il a fallu réintervenir seulement 30 ans après.

Tous ces éléments sont en faveur de la réalité de l'opération de Picault, dont on a pu douter:

V - Conclusion

Il est possible de conclure que les examens et analyses de Laboratoire ont été indispensables à:

- la conduite du nettoyage
- une meilleure connaissance de la technique d'Andréa Del Sarto et des matériaux originaux
- une meilleure connaissance des procédés et des matériaux anciens de restauration.

Ils ont enfin abouti à un essai très positif d'explication du "secret" de la transposition de Robert Picault.

NOTES (1) le XVIè siècle florentin au Louvre Dossier 25 p.66-68. Gilberte-Emile Mâle: La première transposition au Louvre en 1750: la Charité d'Andréa Del Sarto - La revue du Louvre Juin 1982
(2) Catalogue raisonné des tableaux du Roy. Paris 1752 Tome 1er p.43-44.
(3) Catalogue des tableaux du Cabinet du Roy au Luxembourg-Paris 1750 p.7-8.
(4) Arch. Nat.: $O^1 1922^A$ - 1749-50
(5) Arch. Nat.: $O^1 1915$ - 1780 - vol 5 n0 176
(6) Arch. Nat.: $O^1 1922$ - 1789-90
(7) Arch. Louvre : Comptabilité au IX
(8) Ibid
(9) Arch. Louvre : Comptabilité 1845-II
(10) Arch. Nat. : $O^4 2303$ - $O^4 2352$ - $O^4 2353$ (18 Mai 1846-4 Novembre 1847).
(11) Analyses du 19 Novembre 1980 par J.P. Rioux, chimiste du LRMF.
(12) Analyses du 23 Janvier 1981 Opus. cit.
(13) Analyses du 19 Novembre 1980 Opus. cit.
(14) Journal de Trévous-statkine reprints-1969t.L1 Février 1751.
(15) Arch. Nat.: $O^1 1922^B$
(16) Ibid
(17) "Picault devait préparer de l'acide nitrique en phase vapeur par action de l'acide sufurique chaud sur le nitrate de potassium (nitre ou salpètre). La réactivité de ces vapeurs est particulièrement marquée sur nombre de subltances: de multiples substances minérales sont transformées en nitrates solubles (à part les phosphates, les silicates et les sulfates). Les oxydes, les carbonates, les sulfures, les chlorures, les acétates constituant un grand nombre de pigments naturels ne résistant pas à son action. Sur les substances organiques l'action de l'acide nitrique est triple: il peut provoquer l'hydrolyse rapide de substances macromoléculaires naturelles (colles de toute nature, huiles oydées, vernis etc...) entraînant leur liquéfaction par effrondement de la structure macromoléculaire sans compter des possibilités éventuelles d'oydation et de nitration" (J. Petit).

COMPLEX SCIENTIFIC EXAMINATION OF THE 15th CENTURY ST. GEORGE SCULPTURE FROM THE MOSCOW KREMLIN

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SUMMARY

A technical and technological examination was carried out of the polychromatic sculpture of St. George made of limestone by the outstanding Russian sculptor Vasily Yermolin. The sculpture was badly damaged, restored, and broken into pieces in the 20th century. A complex of nondestructive investigations helped obtain information of how the artist had modelled the sculpture and to establish methods and technique used in its design. It was for the first time in the restoration practice that a method of projective stereo-photogrammetry was employed, which made it possible to compute the original form of the lost fragments using old archives photograps.

The polychromatic sculpture of St. George the Dragon - alayer executed by Vasily Yermolin in the 15th century and originating from the State Museums of the Moscow Kremlin is of an exceptional value for Russian culture. The history of the Russian Middle Ages has very scant information of the time of creation and the authors of few surviving monuments. The names of many famous old Russian artists are known to us from legends and chronicles, and can be related to some or other surviving monument with greater or lesser accuracy only thanks to the research of art critics and historians. And the only exception is the name of the architect and sculptor Vasily Yermolin, having been mentioned in the copy of the so called "Yermolin's Chronicle" discoved at the beginning of the 20th century. The Chronicle states that the sculpture of St. George made by Vasily Dmitrievich Yermolin, was mounted on the main gate of the Moscow Kremlin on the 15 of July, 1464, in honour of the saints Flor and Laur.
This monument is valuable to the Russian history, and also significant due to the fact that later on its image became the coat of arms of the City of Moscow, which fact attaches to it not only religous but also State importance. The old Frol Tower was pulled down in 1491, and the present - day Spasskaya Tower was built on its site. The sculpture was removed to the Ascension Monastery which is in the territora of the Kremlin and, in 1634, to the Church of Michael Malein specially built in the monastery. During the time of its existence the sculpture was badly damaged and reconstructed anew, re-made in details, repeatedly painted over and finally, through a mistake of one of the museums workers in 1929 was fully dismantled, as a result of which the torso of St. George was preserved and is exhibited in the State Tretyakov Gallery, but the lower part of the horseman, the horse and the dragon remained only in the form of separate incidental fragments.
By reason of the paramount importance of this monument it was decided to make a complex examination of it employing all the modern scientific methods available. The technical investigations of stone sculpture were ordinarily made in the restoration practice sporadically, by way of separate X-ray examinations, with the assistance of methods of scientific photography, the chemical analysis of the material composition, etc., and not in the nature of an entire complex programme.
The complex examination programme of the sculpture of St. George the Dragon-slayer was divided by us into three stages: (1) a study of the degree of preservation of the author's sculpture; (2) an examination of technical peculiarities of the artist's methods; (3) a hypothetical reconstruction (by way of diagrams, drawings and a copy) of the original shape of the sculpture.
The sequence of carrying out the examination is of great importance as the study of the artist's technique and the reconstruction of the original shape of the monument must be made only after it has been thoroughly examined and later additions, renovations and destructions which may mislead the examiner and disguise the artis's technique, have been found.
The following problems were to be solved when determining the degree of preservation of the monument:
1. determine the number and spatial arrangement of fragmonts of which the torso of St. George broken earlier, was pasted together;
2. find the original pieces of stone among the the later additions and renovations;
3. determine the preservation of the polychromatic painting.
The following were selected as the principal features characterizing the artist's technique:
1. the composition of the material of the sculpture and its construction, i. e. the method, existence and connection of separate stone blocks;
2. the method of the treatment of the surface;
3. the system of the polychromatic painting.
The following physical methods were employed to answer these questions:
1. X-ray Examination.
The radiography of separate fragments showed vividly that the sculpture was originally made of separate stone blocks well adjusted to one another and possibly pasted together with gum. Holes were drilled in stone pieces after it had been repeatedly damaged as a result of fires and wars, and wooden and metal pins were inserted into them forming the frame of the sculpture. The fragments resulting from damage were pasted together with different compounds including cement. The same compounds were used to make good losses or to make whole certain missing detailes, for instance, the lower lip of the dragon and its wing. X-ray photographs of separate equally thick samples of the material made it possible to compare their macrostructure and radiographical density. The results of this comparison enable us to regard the material of most fragments as identical. This assumption was confirmed by the results of the petrographical analysis of the stone.
Radiography was made by radiation from an X-ray tube with the anode plate voltage of 120 kv and contrast X-ray film.

2. Photographic Examination.

The photographing of the torso of St. George in slanting beams with the use of colour filters made it possible to isolate the points of restoration pasting on the head and breast of the horseman. Macrophotographie of the surface of the polychromatic sculpture and microphotographs of microsections showed the exi-

stence of at least two coats of painting with the newly made prime coating and a large number of various coats of paint of later origin evidencing repeated renovations of the monument. A visual examination and macrophotographs of the stone surface made it possible to identify three types of chiseling tools: (the author's) adze and two kinds of triple-pointed chisel. Since traces of the chisel were found not only on the stone, but also on the restoration pastings, they may be considered to have appeared later, which is another confirmation of the fact that the prime coating on the stone with the same traces of the tool as on the pasting, does not belong to the author.
A visual examination in the infra-red and ultraviolet rays did not produce new information of the monument other than an additional confirmation of the existence of pastings.

3. Sterephotogrammetry.

Perspective stereophotogrammetry was repeatedly used when restoring cultural monuments in order to produce scientific documentation, to study various deformations, reconstruction of lost details, etc. We undertook operations to reproduce the form of the lost part of the body of the horse on the basis of the photogrammetrical treatment of incidental remaining archives photographs. To solve such kind of problems methods of traditional perspective stereophotogrammetry are normally used. Photographs are required, however, with the known elements of internal orientation made with special cameras for the employment of such methods. But archives photographs had been more often taken at different times with non-metric cameras from different accidental angles of approach. Hence, the poor quality of pictures, their difference in scale and changes owing to changes in the object of examination.
The theory of perspective photogrammetry does not make it possible to do an accurate processing of such photographs. Projective stereophotogrammetry makes a much more accurate determination of coordinate points by means of incidental archives photographe. The methods of projective stereophotogrammetry (1) developed in the USSR are based on the construction of a projective model and its external orientation. The spatial coordinate points of the object were calculated by elements of orientation, by means of mattix algebra and iterative calculus employing the method of minutest squares. The foreshortened archives photographs of the sculpture of St. George in the interior of the church were used for calculations. The difficulty in the processing of these photographs was aggravated by the fact that their geodesic preparation was non-existent, and the spot on which the sculpture was mounted did not remain. Nevertheless we succeeded in measuring 70 points. In doing so the horisontal of the floor and the vertical of the arch, in which the sculpture was photographed, were selected for geodesic orientation. The scaling by the coordinate axes was made with the aid of surviving fragments of the horseman. The measurements were taken by the SKΛ-18 stereocomparator which made it possible to process different - scale photographs. An algorythm and programme of the processing of photographs in the algorythmic language "Fortran-4" for the ES-1022 computer were compiled in order to implement the proposed theory. As a result of the processing of photographs the spatial coordinate points of the object were obtained with the accuracy of 0.5 sm. The result are shown in photographs by way of isolines which may serve as reference-points when reproducing the form of a lost fragment. In order to verify the accuracy of the method the coordinate points of the surviving head of the horse were calculated, which demonstrated good conformity with the actual dimensions.
The entire programme of complex examination outlined above was planned as a long-range one and has not yet been completed. The executed part of this work seems to be sufficiently interesting and of independent significance. It yields information of the methods employed by the outstanding sculptor Vasily Yermolin in the creation of the monument, as well as making it possible to produce genuine scientific documentation for its subsequent restoration and reconstruction.

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ANALYSE DE LA COMPOSITION ELEMENTAIRE DE COUPES DE PEINTURE PAR MICROSONDE ELECTRONIQUE

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SOMMAIRE

La caractérisation physico-chimique des pigments employés dans les peintures de chevalet, donne de précieuses indications sur l'ancienneté des oeuvres et parfois même sur l'origine géographique des minerais.

Après un rappel du principe de fonctionnement de la microsonde protonique, nous présenterons les premiers résultats obtenus par microanalyse de coupes de peintures en vue du dosage non-destructif des impuretés du blanc de plomb.

INTRODUCTION

La détermination des constituants majeurs et mineurs des pigments est importante afin d'orienter la conservation et la restauration des peintures, celle des traces devrait permettre leur authentification et parfois la caractérisation des minerais (1). Cette étude a pour but d'identifier et de tenter de doser les traces du blanc du plomb d'une couche picturale. Ce pigment est utilisé depuis l'antiquité. On le rencontre dès l'époque Han en Chine et sur les peintures du Fayoum en Egypte. Les lieux d'approvisionnement en galène et le mode d'élaboration de la céruse ont varié selon les époques, entrainant des différences de teneurs de certaines impuretés qui peuvent aujourd'hui servir de critères d'authentification des peintures de chevalet.

Le carbonate de plomb naturel semble n'avoir pas été utilisé en tant que pigment. Théophrastre, Pline, Vitruve et Théophile décrivaient ainsi la préparation de la céruse : "Pour fabriquer de la céruse, faites vous amincir des feuilles de plomb ; puis les déposant sèches dans un bois creux, versez-y du vinaigre chaud ou de l'urine, et couvrez. Après un mois, levez le couvercle, et enlevant tout ce qui sera blanc, replacez de nouveau comme auparavant" (2).

La méthode hollandaise consiste, à partir du XVIIIe siècle, à exposer pendant trois mois des languettes de plomb déposées dans un pot d'argile dont le fond contient une solution d'acide acétrique. Le plomb mis en présence de fermentation carbonique, de vapeur acétique, de chaleur, d'oxygène de l'air et de vapeur d'eau, se transforme lentement en carbonate basique qui est ensuite broyé dans de l'huile de lin.

D'autres procédés plus modernes font appel à l'électrolyse ainsi qu'à des méthodes de précipitation qui ont l'avantage d'être plus rapides que la précédente (3).

L'étude la plus concluante menée sur l'identification des impuretés du blanc de plomb a été effectuée par J.P. W. Houtman et J. Turkstra en 1964 par activation neutronique à partir d'un milligramme de matière (4). L'étude de 25 tableaux peints entre 1510 et 1909 et de 18 blancs de plomb modernes provenant de différents fabriquants a montré que le cuivre, l'argent, l'antimoine, le mercure, le zinc, le chrome et le manganèse présentaient des différences de concentrations entre les pigments modernes et anciens.

Impuretés du blanc de plomb

Période	Ag	Cu	Hg	Mn	Cr	Zn	Sb insol.
1510-1650	20,6-26,9	153-221	1,6-16	74-106	1-590	1-8,6	0,01
1654-1849	17,5-25,8	80-205	1,2-6,8	9-76	0,01-36	0,1-61	0,01
1861-1920	0,66-20	4,3-60	0,2-6	2,2-34	0,01-1100	0,5-26000	0,01
1925-1960	0,5-8,5	2,4-63	0,1-0,8	1,1-1,6	0,01-19,1	3,6-5700	0,01-108
postérieure à 1960	1,7-6,5	20,5-28,4	0,1-0,6	0,3-1,6	0,1-0,2	1,3-7,3	0,01

Les teneurs en Cu, Ag, Hg et Mn sont assez fortes et constantes avant 1850 et chutent d'un facteur 10 dans la composition des pigments de fabrication ultérieure.

La purification du plomb par coupellation de l'argent à partir de zinc (procédé Parkes, 1855) (5) est peut-être à l'origine de cette variation de la composition du plomb.

L'augmentation des teneurs en zinc à partir de la même époque correspond plus vraisemblablement à la fabrication du blanc Cremnitz par broyage industriel, source de pollution. Il peut également s'agir d'ajout de blanc de zinc (appelé alors blanc chinois), moins onéreux et préparé à partir de 1830.

On constate également que le chrome diminue à partir de 1650 ce qui ne peut s'expliquer que par un changement d'approvisionnement du plomb. Au contraire, les teneurs en antimoine augmente assez fortement depuis 1960.

Comme il n'est pas envisageable de prélever 1 mg de blanc de plomb sur des tableaux, nous avons fait appel à une nouvelle technique non-destructive de microanalyse de région superficielle qui permet d'opérer directement sur coupe de peinture : la microsonde protonique, unique en France, dont la mise en oeuvre est extrêmement délicate.

PRINCIPE DE FONCTIONNEMENT ET DISPOSITIF EXPERIMENTAL

La microsonde protonique présente beaucoup de similitudes dans son principe de fonctionnement avec la microsonde électronique : l'échantillon à étudier est bombardé par un faisceau de particules chargées bien focalisé et le résultat de leurs interactions avec les atomes constitutifs de l'échantillon est détecté selon des moyens appropriés.

Les particules chargées, les plus couramment employées en microsonde nucléaire pour réaliser des analyses multiélémentaires, sont les protons de 1 à quelques MeV.

Le procédé est non destructif de l'échantillon qui ne nécessite aucune préparation complémentaire et ne produit pas de radioactivité résiduelle.

Dispositif expérimental

A la sortie d'un accélérateur Van de Graaff de MV, le faisceau de particules chargées est soigneusement collimaté par un système de fentes "objet", puis focalisé par un ensemble de quatre lentilles quadrupolaires pour obtenir sur la cible, située dans une chambre sous vide, une image de la fente dont les dimensions sont de l'ordre de quelques micromètres seulement (fig. 1).

Deux paires de plaques déflectrices du faisceau de particules sont placées près du dernier quadrupole et permettent au faisceau incident de balayer la surface de l'échantillon.

La cible sous investigation peut également être déplacée dans un plan perpendiculaire à l'axe du faisceau grâce à un système mécanique de précision.

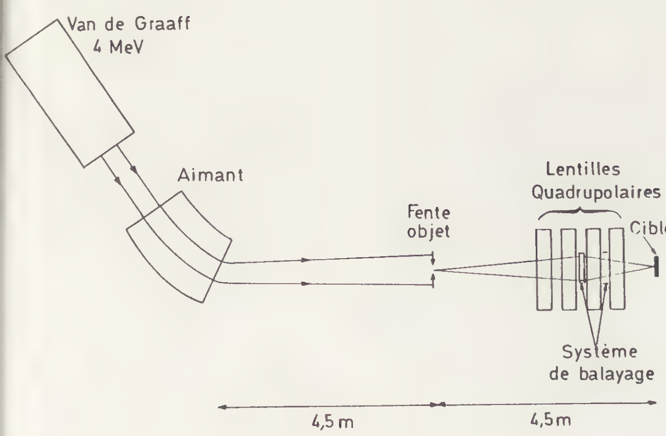

Figure 1 : Schéma du dispositif expérimental de la microsonde protonique

Le repérage du point d'impact sur la cible et la détermination de ses dimensions s'effectue à l'aide de deux microscopes optiques.

La chambre d'irradiation contient, outre le porte-échantillon, la partie sensible du détecteur Si(Li) destiné à l'analyse X et un détecteur à barrière de surface pour l'analyse des particules rétrodiffusées ou émises par suite de réactions nucléaires.

Possibilités analytiques

La composition élémentaire de microcoupes de peintures est obtenue par détection de l'émission X induite par le faisceau de protons incidents.

Tous les éléments de numéro atomique supérieur à 12 peuvent être détectés avec des limites de détection proches du µg/g, si on choisit une énergie convenable pour les protons incidents.

On admet, généralement, qu'il faut :

E_p inférieure à 1 MeV pour les éléments de $Z < 20$ raies K

E_p de l'ordre de 1 MeV pour les éléments de $Z \simeq 20$ raies K et de $Z \simeq 60$ raies L

E_p de l'ordre de 2 MeV pour les éléments de $Z \simeq 30$ raies K et de $Z \simeq 70$ raies L

E_p de l'ordre de 3 MeV pour les éléments de $Z \simeq 35$ raies K et de $Z \simeq 85$ raies L

L'énergie des protons incidents retenue pour l'étude de la composition multiélémentaire d'un échantillon devra tenir compte des éléments présents en faible quantité auxquels on s'intéresse particulièrement.

Dans certains cas, il est nécessaire de réaliser des spectres X du même échantillon à deux énergies E_p différentes.

PREPARATION DES ECHANTILLONS

Le prélèvement de peinture effectué à l'aide d'une seringue hypodermique est enrobé dans de la résine polymérisable à froid qui est ensuite coupé transversalement pour faire apparaître la stratigraphie des microchouches picturales.

Un polissage à l'alumine ou au diamant, contrôlé au microscope, termine la préparation de cet échantillon de très faibles dimensions (100 à 200 micromètres dans un bloc de résine de plusieurs millimètres de côté).

EXAMEN DES ECHANTILLONS

La microphotographie de la coupe, prise au microscope optique, renseigne sur le nombre des couches et leur couleur.

L'analyseur de coupes, mis au point au L.R.M.F. et qui permet d'opérer sur des surfaces de l'ordre de la ppm, caractérise les constituants majeurs et mineurs dont on peut déduire la nature des pigments utilisés pour chaque couche, sans toutefois pouvoir déceler les éléments traces, "empreinte digitale" du pigment.

L'emploi de la microsonde protonique a été envisagé car elle devrait permettre l'identification et le dosage non-destructif de traces dans un pigment tel que le blanc de plomb. Les différences de concentration observées sur certains éléments correspondent soit aux impuretés naturelles du minerai utilisé, soit à des impuretés ajoutées ou soustraites selon le mode de fabrication qui a varié suivant les époques.

Lorsque des différences de teneurs apparaissent, il est très important de vérifier si elles sont significatives car elles peuvent constituer un critère d'authentification des peintures puisqu'un faussaire, même de génie, ne pourrait pas synthétiser la composition exacte des pigments qu'il voudrait imiter.

Quelques essais exploratoires ont donc été menés au moyen de la microsonde protonique, du Centre d'Energie Nucléaire, sur plusieurs microcoupes de peintures afin de définir le mode opératoire à adopter ultérieurement pour de telles analyses.

Un microfaisceau de protons avec les caractéristiques suivantes :

. diamètre : 3 µm
. énergie : 3 MeV
. intensité : 0,25 10^{-9} A

a été utilisé en mode balayage et en mode fixe.

Si la mise en place précise d'une couche déterminée sous un faisceau d'ions est relativement aisée pour des prélèvements comportant seulement quelques strates bien définies, elle se révèle plus difficile pour des prélèvements de structure complexe tels que celle des primitifs où les couches de faibles épaisseurs sont nombreuses.

Limites spectrales

Entre les raies de la série M et de la série L du plomb, c'est-à-dire entre, environ, 3 et 5 KeV, il est possible d'analyser un certain nombre de raies K des éléments de numéro atomique (Z) compris entre 19 (potassium) et 30 (zinc) et les raies L des éléments de numéro atomique compris entre 47 (argent) et 77 (iridium) avec des possibilité d'interférences non négligeables :

Par exemple Ti $K_{\alpha 1,2} \longrightarrow$ 4,508 KeV

Ba $L_{\alpha 1} \longrightarrow$ 4,465 KeV

Au delà de 9 KeV, l'identification d'éléments par leurs raies caractéristiques doit tenir compte de l'existence des nombreuses raies L du plomb, constituant majeur de la céruse. Les résultats obtenus (fig.2) montrent la nécessité d'un temps d'intégration du spectre beaucoup plus élevé puisque le nombre de coupes intégrées, qui sont caractéristiques des impuretés, est limité à 150 (fig. 3).

La recherche des conditions opératoires optimales pour le blanc de plomb a été effectuée à l'aide d'une millisonde PIXE sur des étalons de plomb.

L'emploi d'un filtre absorbant d'aluminium de 17 µm d'épaisseur atténue fortement les raies M de basse énergie, et très intense du plomb lors de l'excitation d'étalons par un faisceau de protons de 3 Mev. Cette condition expérimentale évite un temps mort élevé qui dégraderait la résolution et provoquerait l'apparition de pics d'empilement aux énergies doubles.

Alors que sur le spectre non filtré, n'apparaissent que les raies du plomb, le rayonnement filtré par la feuille d'aluminium révèle les raies L de l'antimoine et K du fer et du cuivre comprises entre 3 et 9 KeV (fig. 4).

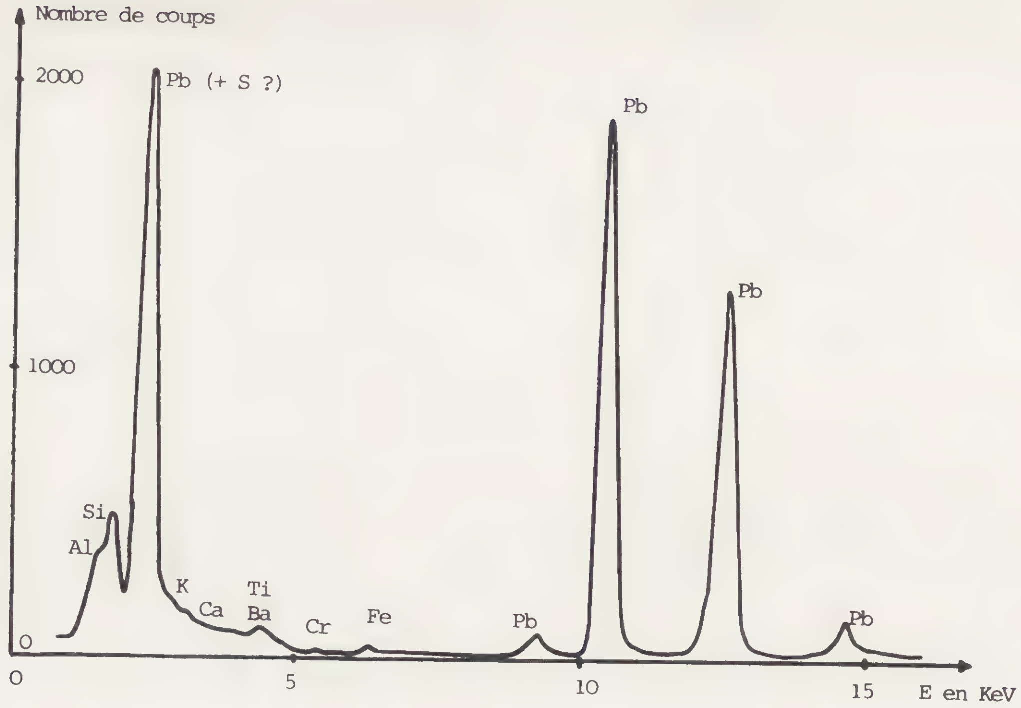

Figure 2 : Spectre du blanc de plomb du "Jeune apprenti" de Modigliani

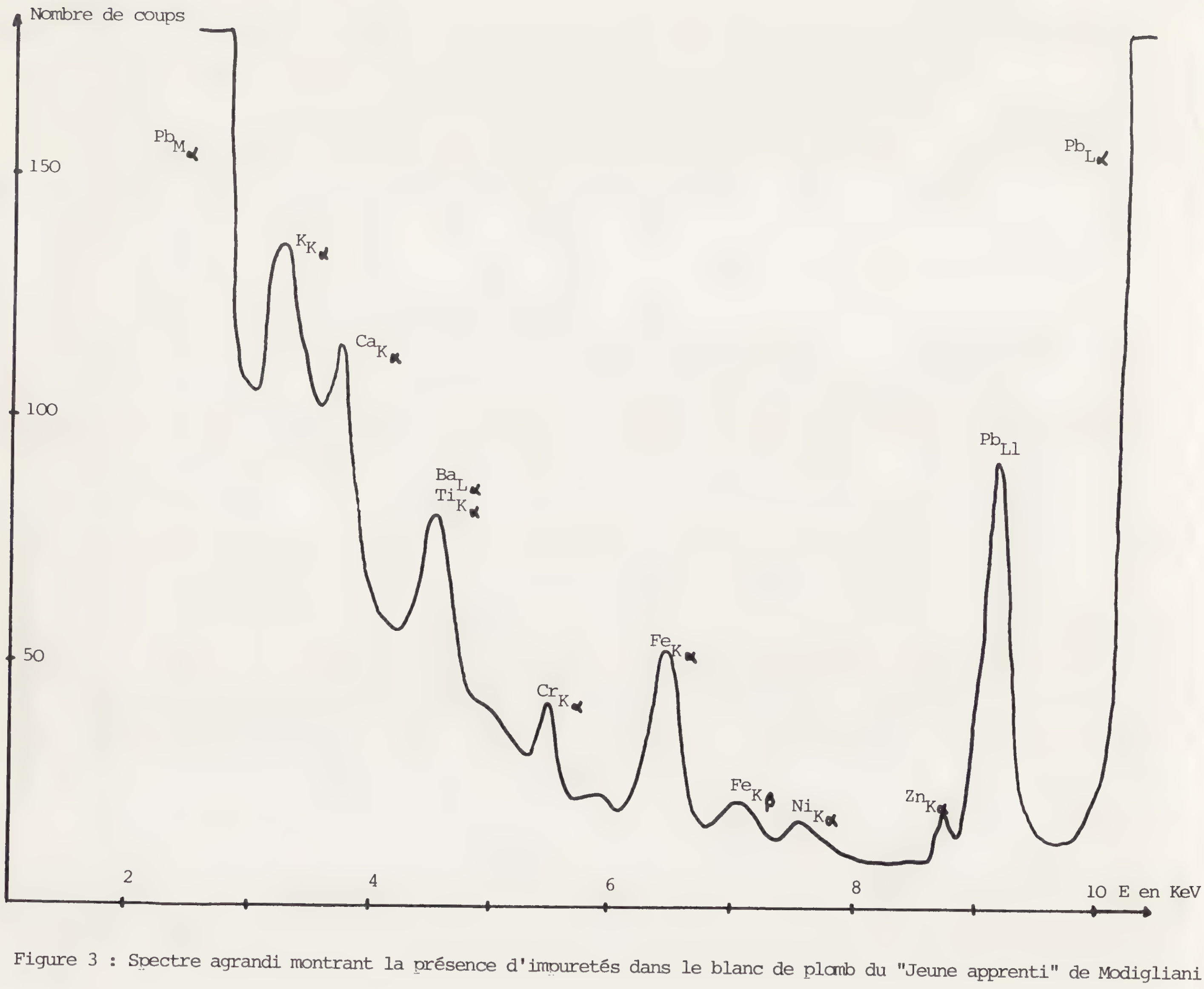

Figure 3 : Spectre agrandi montrant la présence d'impuretés dans le blanc de plomb du "Jeune apprenti" de Modigliani

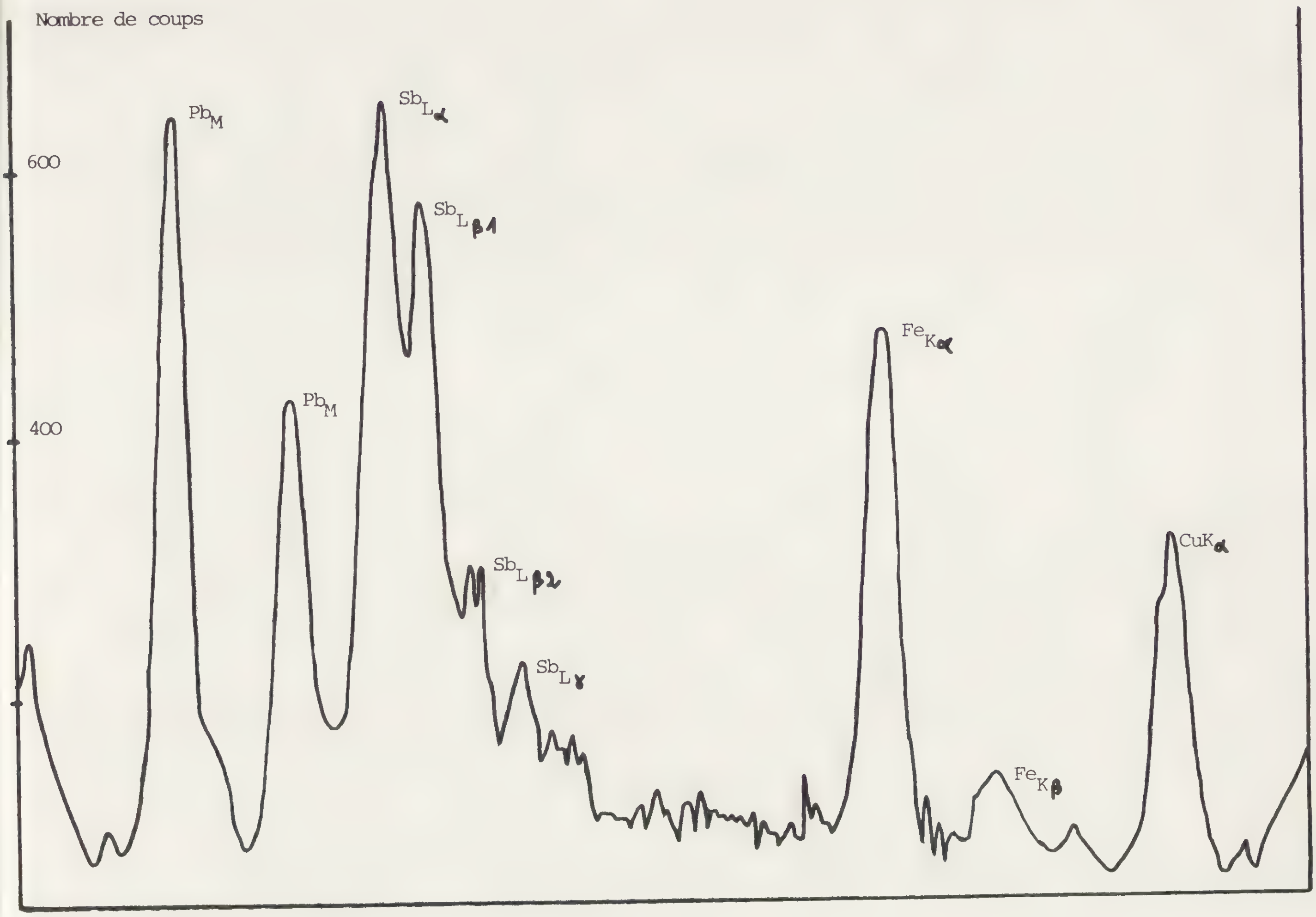

Figure 4 : Analyse d'un étalon de plomb par millisonde PIXE 1 MeV. Essai de filtration avec 17 µm d'aluminium
37 nA - 30 µC - t = 1000 s

Un protocole expérimental a été défini dans ces conditions expérimentales pour repérer par balayage préalable la couche de plomb à analyser. Les balayages successifs à différents niveaux de la couche de blanc de plomb permettra d'illustrer la répartition des éléments chimiques au sein de la couche et de s'assurer ainsi de l'homogénéité de composition du pigment. Rappelons que des protons de 3 MeV pénètrent d'environ 50 µm dans le blanc de plomb et que les profondeurs d'où sont émis les rayons X dépendent de leur longueur d'onde plus où moins absorbée par la céruse.

Les résultats partiels en cours d'exploitation seront commentés ultérieurement.

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PRECISIONS SUR LA TECHNIQUE D'EXECUTION DES PEINTURES DE GERARD DAVID

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Résumé

La technique picturale de Gérard David, peintre flamand de la fin du XVème siècle, est précisée grâce à l'examen ponctuel de plusieurs de ses oeuvres d'attribution reconnue. L'examen en réflectographie dans l'infra-rouge mené en collaboration avec M. Ainsworth du Metropolitan Museum of Art a permis de caractériser le dessin sous-jacent de G. David. Le relevé des outils particuliers qu'il utilise : plume, pierre noire, poncif, complète d'autre part notre connaissance de la technique de dessin des Primitifs flamands. Enfin l'examen des tableaux au microscope binoculaire, des radiographies et de quelques rares coupes transversales est venu confirmer certaines des hypothèses de travail émises à Ottawa (1981) sur la technique du modelé propre au maître.

Dans notre communication présentée au Congrès de l'ICOM à Ottawa : Méthodes scientifiques d'examen à mettre en oeuvre pour améliorer les connaissances de la technique picturale des primitifs flamands, nous formulions quelques hypothèses de travail quant à la technique picturale de G. David et nous faisions appel, pour étendre les recherches en cours, à une collaboration internationale entre scientifiques(1). Des études ponctuelles de plusieurs oeuvres clés du maître s'avèraient nécessaires. Celles-ci ont été menées par M. Ainsworth, research Investigator, au Metropolitan Museum of Art et par nous au laboratoire de Recherche des Musées de France avec la collaboration de N. Raynaud, L. Faillant-Dumas et Chr. Lahanier et au Musée Groeninge de Bruges avec celle de Ms. De Vos et G. Van de Voorde. Nous avons aussi examiné la Nativité de G. David conservée au Musée hongrois des Beaux-Arts de Budapest (2).

Nous sommes ainsi à même aujourd'hui d'apporter des précisions sur la technique du maître à partir de données inédites fournies principalement par l'examen en réflectographie dans l'infra-rouge mais aussi par l'étude de radiographies d'un grand nombre de ses peintures d'attribution reconnue.

Pour obtenir une image précisée du modelé propre à Gérard David, nous étudierons le dessin sous-jacent conjointement à l'exécution picturale.

Caractérisation du dessin sous-jacent

Une série d'observations d'ordre général peuvent de prime abord être formulées. C. David est, selon nous, le Primitif flamand qui a utilisé, en les combinant, la plus grande variété d'instruments pour exécuter ses dessins : le pinceau, la mine de plomb, la plume mais aussi la pierre noire. De plus, il associe fréquemment à ces moyens l'usage du poncif(3).

Que le dessin sous-jacent de Gérard David soit exécuté à main libre ou dans une première phase à l'aide d'un poncif, il se présente sous deux aspects très différents, observables parfois simultanément dans une même oeuvre : un dessin de type traditionnel, constitué de petits plans de hachures diagonales, parallèles et serrées, d'un tracé au pinceau rigoureux et un dessin esquissé, le plus souvent tracé à la pierre noire et d'aspect très désordonné. Dans ce dernier cas l'écriture confuse, rapide et pleine de reprises successives de G. David se différencie de celle des Primitifs flamands du début du siècle qui est structurée et orientée. Elle constitue même une originalité du maître par rapport à celle de ses contemporains.

Illustrons chacune de ces observations sur les oeuvres que nous avons examinées :

- La Nativité, Musée hongrois des Beaux-Arts, Budapest (avt. 1497)
- Le triptyque Sedano, Louvre, Paris (ca. 1490 - 95)
- Le Jugement de Cambyse et le Supplice de l'Innocent, Musée Groeninge, Bruges (daté 1498)
- Le Baptême du Christ et revers, Musée Groeninge, Bruges (ca. 1508)
- Dieu le Père entre deux Anges, Louvre, Paris, (ca. 1508)
- Les Noces de Cana, Louvre, Paris (ca. 1505)
- La vierge parmi les Saintes, Musée des Beaux-Arts, Rouen (1509)

Le pinceau

G. David comme tous les Primitifs flamands, emploie le pinceau, toutefois à la différence de Van Eyck, il en combine souvent l'usage avec celui d'autres instruments. Ce dessin est de type traditionnel : trait net et rectiligne pour la mise en place des plis, hachures parallèles et serrées d'un tracé soigné pour les plages d'ombre des carnations ou des drapés. On en relève par exemple dans la robe de la Vierge du Triptyque Sedano et dans les figures d'Adam et Eve, la mise en place de toute la composition étant par contre préfigurée au poncif. Un dessin au pinceau apparaît aussi dans les vêtements de la Vierge entourée de Saintes du Musée des Beaux-Arts de Rouen, juxtaposée cette fois à un dessin à la plume et à la mine de plomb qui fournit une ébauche très légère des grandes masses de la composition.

La plume

La plume, rarement mentionnée lorsqu'on traite du dessin sous-jacent des Primitifs flamands, est largement utilisée par G. David pour camper quelques traits importants des compositions, pour mettre en place les plis principaux d'un drapé et ses zones d'ombre, pour rendre certains contours plus vigoureux.

Son écriture est alors autoritaire mais rapide. Dans les Panneaux de Justice de Bruges par exemple (Fig. 1) les plans d'ombre des vêtements sont indiqués par un dessin à la plume vigoureux. On ne peut parler, comme pour le dessin au pinceau de Van Eyck ou de Bouts, de hachures parallèles mais plutôt d'une succession de traits enlevés de longueurs et d'écartement très variables. A plusieurs emplacements un deuxième réseau de hachures vient s'insérer dans le premier ou même s'y superposer pour marquer un temps fort du modelé. La configuration des traits est changeante : variation d'épaisseur, d'effilement, de raideur, etc... Enfin la charge de matière n'est pas très constante ce qui provoque par endroits des interruptions de tracé et à d'autres des dépôts sous forme de taches. Ces particularités de graphisme indiqueraient l'usage d'une plume d'oiseau plutôt que de roseau.

Un même style d'écriture se retrouve dans le dessin sous-jacent de la Nativité de Budapest et dans les quelques zones d'ombre profonde du drapé de la robe de Sainte Catherine du tableau de Rouen.

La pierre noire

Un dessin sous-jacent à la pierre noire n'avait été constaté jusqu'ici que dans une oeuvre de G. David : l'Adieu du Christ à sa Mère(4). Le maître l'utilise pourtant dès ses premiers tableaux mais seulement pour des parties de composition, principalement pour indiquer les plans d'ombre. Toutefois on trouve aussi des linéaments de certains visages et des plis de drapé mis en place à la pierre noire. La facture est étrangement hâtive et assez dure, le dessin nerveux et tout à fait imprécis dans son tracé, est constamment corrigé. Les lignes non suivies lors de l'exécution picturale sont très nombreuses et entraînent souvent une confusion de lecture.

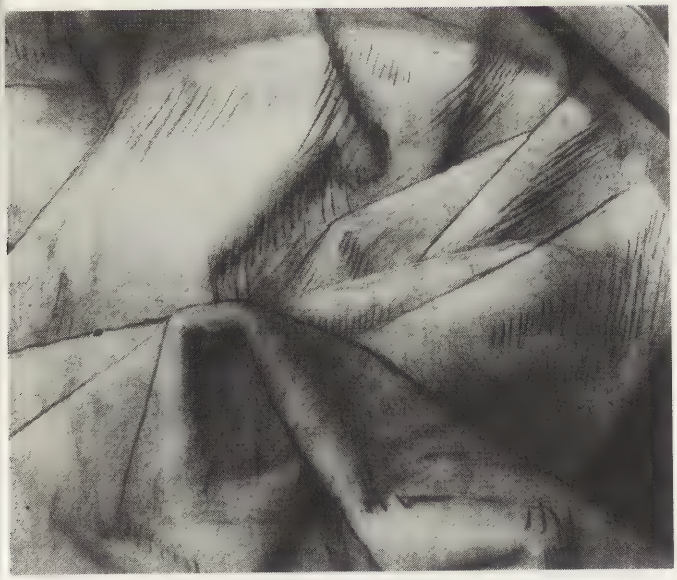

Fig. 1 : G. David, Le Supplice de l'Innocent, Bruges, Musée Groeninge, détail dans l'infra-rouge du manteau jeté sur le sol. Dessin à la plume (Copyright A.C.L., Bruxelles)

L'acuité très variable des tracés, due au toucher "tendre et gras" de la pierre (5) qui adhère irrégulièrement à la préparation imperméabilisée et dont la pointe s'émousse à l'usage, permet, nous semble-t-il d'identifier cet instrument avec une quasi certitude(6)

Des traits successifs préparent ainsi la mise en place des plis de la robe du juge (fig. 2 a) dans la Justice de Cambyse et de celle du Christ dans l'Adieu à sa mère et dans les Noces de Cana. Dans cette dernière oeuvre la pierre noire se superpose à un dessin au poncif. L'ensemble étant d'aspect très embrouillé.

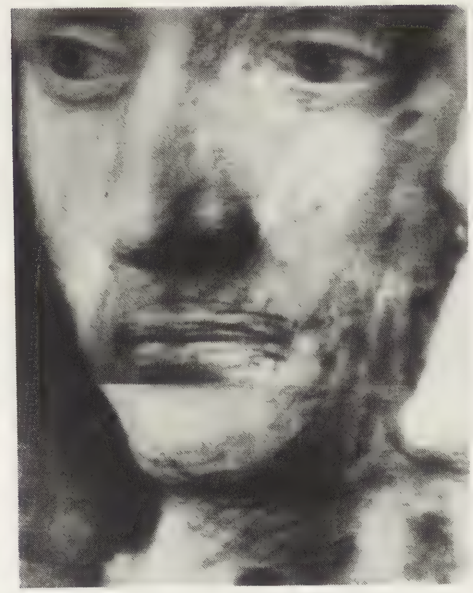

Fig. 3 : G. David, Panneaux de Justice, Bruges, Musée Groeninge, détail par réflectographie infra-rouge du visage d'un assistant. A la pierre noire (Copyright A.C.L., Bruxelles)

Dans les Panneaux de Justice le dessin des visages de plusieurs conseillers est à son tour esquissé par de fins traits à la pierre noire qui situent les yeux, la bouche, le menton (Fig. 3) de manière particulièrement brouillonne tandis que de rapides tracés continus en dents de scie marquent les plans d'ombre. Ce nouveau graphisme courant chez G. David qui l'utilise le plus souvent pour ombrer les cous (Baptême du Christ, Panneaux de Justice ...) ou des pans d'étoffe (Retable de Saint Nicolas, Justice de Cambyse (Fig. 2 a - b)) consacre l'élargissement du vocabulaire formel du dessin sous-jacent du premier quart du XVIe siècle.

Fig. 2 a) : G. David, la Justice de Cambyse, Bruges, Musée Groenninge, détail dans l'infra-rouge du manteau du juge.
b) : Retable de Saint-Nicolas, Edimbourg, Gallerie Nationale d'Ecosse, détail dans l'infra-rouge de la robe

Dessin au poncif

Le dessin au poncif n'avait été décelé jusqu'à ce jour que dans des oeuvres de G. David dont l'attribution était discutée, parce qu'elles existaient en plusieurs exemplaires, comme la Vierge à la Soupe au Lait et La Vierge et le Christ mort, ou encore dans des copies comme l'Adoration des Mages d'après Van der Goes (7). Or nous le relevons aussi dans les tableaux autographes du maître.

Le dessin au poncif des oeuvres de G. David frappe par le peu de soin apporté à son exécution (Fig. 4 a - b); les points, le plus souvent épais et irréguliers, sont mal alignés et présentent des charges de matière très variables (8). Ce dessin campe non seulement les contours des figures mais prépare aussi des détails de forme et de modelé. Son usage n'exclut pas les repentirs qui sont fréquents. Il sert le plus fréquemment à situer les traits des visages et en particulier les contours des yeux et de la bouche, les volumes des mains et des pieds. Cependant, on en décèle aussi dans les cheveux et les barbes (St-Jean du Baptême du Christ et Dieu dans Dieu le Père entre deux Anges, dans les motifs de brocart (chape de Dieu le Père du même tableau (Fig. 5 a - b) et, constatation plus étonnante, dans certaines plages d'ombre pour marquer l'emplacement des hachures (carnation de la Vierge, d'Adam et d'Eve du Triptyque Sedano). A ces endroits les points se lisent en réflectographie dans l'infra-rouge sous les hachures au pinceau ou sous les traits à la pierre noire qui les recouvrent.

En général ce dessin au poncif est difficile à repérer, parce que G. David l'efface partiellement avant la mise en couleur ou masque les points en reprenant les contours, parfois déjà au stade du dessin sous-jacent (revers du Baptême) et sinon en surface par de larges cernes foncés. L'examen local (avec agrandissement) par réflectographie dans l'infra-rouge s'est donc avéré un auxiliaire important pour compléter les informations trop fragmentaires fournies par les rares photographies dans l'infra-rouge existantes.

Parmi les oeuvres examinées c'est certainement le tableau de Dieu le Père entre deux Anges du Musée du Louvre, d'une grande qualité picturale et d'une facture très serrée qui offre l'exemple le plus inattendu d'utilisation d'un dessin au poncif : seuls les cernes bruns d'une largeur très inégale, qui reprennent tous les contours, pouvaient conduire à le soupçonner.

On trouve aussi un dessin au poncif dans les Panneaux de Justice, un usage plus large de cet outil étant fait dans la composition du Supplice. Ce type de dessin est le plus lisible dans la tunique du bourreau agenouillé près de Sésame (Fig. 6). On note des variations dans le diamètre des points qui ne sont ni joints, ni recouverts par un trait au pinceau ou à la plume, par contre leur espacement est assez régulier. Le dessin est ensuite complété à main levée. On relève également un dessin au poncif dans les plis d'autres vêtements de la composition où à plusieurs reprises les tracés initiaux sont modifiés ou abandonnés. Enfin quelques traces de dessin au poncif apparaissent encore dans les visages et les mains des personnages principaux. La même manière mécanique de mise en place des plis s'observe encore dans la robe de la Vierge du Baptême (Fig. 4 a). Néanmoins, dans cet exemple, un trait à la plume repasse sur les points. Pour plusieurs plis ce trait est même doublé. Serait-ce là une façon de marquer l'étendue de l'ombre dans les creux de l'étoffe ? Dans la Nativité par contre, oeuvre de jeunesse du maître, les traits des visages et les plis des drapés sont dessinés à main levée, à

Fig. 4 a) : Vierge et Enfant, revers du Baptême du Christ, Bruges, Musée Groeninge, détail dans l'infra-rouge du bas de la robe de la Vierge.
b) : Retable de Saint-Nicolas, détail dans l'infra-rouge du lit et des trois jeunes filles. Dessins au poncif, pigment (?) (Copyright, A.C.L, Bruxelles)

la plume et au pinceau, et seuls les détails de paysages (chaumières, volume des arbres ...) sont exécutés au poncif. Dans la Vierge parmi les Saintes de Rouen le poncif a visiblement été employé pour reproduire l'auto-portrait de G. David. Pour le reste, l'oeuvre n'ayant pas été examinée en réflectographie dans l'infra-rouge, il est difficile d'évaluer l'utilisation réelle de ce moyen de reproduction mécanique d'autant plus que la photographie dans l'infra-rouge montre un usage simultané du pinceau, de la plume et de la mine de plomb. Mais c'est dans un des panneaux du Retable de Saint-Nicolas que le dessin au poncif est le plus lisible. Il indique clairement les plis du drap de lit et campe le volume des visages et des coiffes des trois jeunes filles. A plusieurs endroits ce dessin n'a pas été suivi lors de l'exécution picturale et l'alignement des points est resté tel que (Fig. 4 b).

Cet ensemble de documents éclaire d'une lumière nouvelle le concept du poncif; le cadre traditionnel de la simple copie doit être élargi. En effet, si G. David utilise des dessins à échelle définitive pour situer la composition, puis la reproduire, la présence d'un dessin au poncif dans une peinture ne trahit pas nécessairement la copie. Ce type de dessin au contraire ferait partie intégrante du processus de création.

G. David possédait-il une grande quantité de dessins perforés qu'il pouvait reproduire indifféremment dans ses tableaux ou s'agissait-il de simples dessins préparatoires faits sur le vif et perforés ultérieurement pour être intégrés à une composition ? La première hypothèse nous paraît improbable parce que l'on n'observe pas la reprise des mêmes éléments principaux dans des oeuvres différentes. Nous pensons plutôt que G. David campait les formes au moyen de ses dessins avant de les préciser, afin de ne pas salir la préparation blanche par des corrections

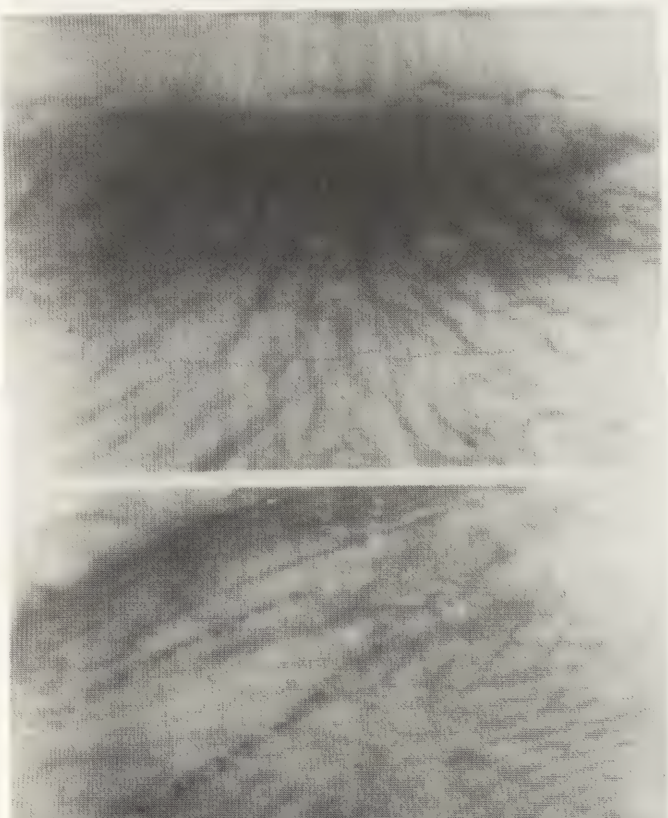

Fig. 5 : G. David, Dieu le Père entre deux Anges, Paris, Musée du Louvre, détails en réflectographie infra-rouge de la barbe et du brocart de Dieu, dessins au poncif (Clichés laboratoire de Recherche des Musées de France)

successives. L'aspect souvent brouillon de son dessin sous-jacent et les fréquentes modifications de mise en place des formes lors de l'exécution picturale montrent d'ailleurs une certaine difficulté à concevoir la composition dès l'origine tandis que l'absence de dessin sous-jacent à main levée, dans plusieurs visages d'exécution serrée, ceux du Juge et du roi des Panneaux de Justice par exemple, appuyerait l'hypothèse de l'emploi d'un poncif dont on aurait effacé partiellement les traces, comme dans le tableau de

Dans les deux types de dessin coexistant dans l'oeuvre de G. David - sans compter le dessin au poncif - le dessin esquissé prédomine et il préfigure par sa liberté encore plus grande que dans l'oeuvre de Memling, une des caractéristiques majeures du dessin du début du XVIe siècle. Cette particularité serait passée inaperçue sans un recourt systématique aux examens en réflectographie dans l'infra-rouge, l'exécution picturale soignée du maître ne laissant pas prévoir la rapidité de facture d'un grand nombre de ses dessins sous-jacents. Dans les Panneaux de Justice une

Fig. 6 : G. David, Supplice de l'Innocent, détail par réflectographie infra-rouge de la tunique du bourreau. Dessin au poncif (Cliché copyright A.C.L. Bruxelles)

écriture désordonnée et même confuse ne s'observe que dans le dessin des figures secondaires alors que leur exécution picturale reste serrée. Les autres personnages , présentent soit un dessin au pinceau, soit frappent par une absence de dessin, à l'exception de rares traits, et par la présence de quelques points apparents surtout dans la région des yeux. Cette relation entre le choix du type de dessin et la hiérarchie des personnages est-elle le fait de G. David ou peut-on en déduire une distribution du travail dans l'atelier ? Il est prématuré de répondre à cette question mais elle doit être conservée en mémoire lors des examens ultérieurs.

Les analogies d'écriture relevées par M. Ainsworth entre le dessin sous-jacent de G. David et ses dessins autonomes apportent des données nouvelles de comparaison qui pourraient ouvrir d'intéressantes perspectives dans ce délicat domaine des attributions (9).

Caractérisation de l'exécution picturale

Dans notre thèse de doctorat nous situions la place occupée par G. David dans l'évolution du modelé du XVIe siècle (10). Les hypothèses formulées à ce moment sont maintenant confirmées par l'examen d'un plus grand nombre d'oeuvres et de films radiographiques. Par rapport à la technique d'exécution des Primitifs flamands antérieurs, la structure picturale

est simplifiée : le ton couvrant est additionné d'une plus forte quantité de blanc de plomb et le nombre de couches de glacis qui s'y superposent diminue. Toutefois G. David pratique simultanément deux techniques d'exécution, une se rattache encore à la tradition alors que l'autre innove. Dans la première les modelés lisses et émaillés sont souvent traités en un puissant clair-obscur qui n'altère pas l'effet de "volume-lumière" propre aux Primitifs flamands (l'image radiographique présente alors une homogénéité de densité des blancs due à une distribution assez équilibrée du pigment (11)). Dans la seconde la facture est de plus en plus marquée, par des jeux de brosse dans le ton couvrant qui s'est épaissi (l'image radiographique est plus contrastée dans ce cas), ou par de petites touches blanches empâtées, décelables sous le glacis, mais aussi en surface par des rehauts graphiques foncés (12). Ces derniers apparaissent sous forme de séries de brèves hachures parallèles surtout dans les vêtements. Parfois ils renforcent le dessin sous-jacent, parfois ils figurent l'ombre et sont alors recouverts d'une couche de glacis (13). Ces transformations techniques, en particulier la présence de beaucoup de blanc de plomb dans les bleus (Fig. 7 a) et les chairs et ce travail dans la matière, qui rompt avec les modelés antérieurs, sont entre autres très apparents dans les radiographies des Panneaux de Justice et des Noces de Canna (14).
G. David est également le premier Primitif flamand à créer des modelés dans lesquels le blanc de plomb perce par endroits la surface émaillée des glacis. Le peintre travaille souvent de cette manière les carnations des visages, ce qui en souligne l'expressivité. Il semble aussi utiliser des pigments foncés pour peindre les ombres au lieu de superposer les glacis, comme ses prédécesseurs, en vue d'arriver à une saturation optique. Le visage du donateur des Noces de Cana en offre un bon exemple.

Enfin, G. David schématise le modelé des brocarts tout en recourant à une surcharge décorative. Les fils ors nombreux sont de densité égale quel que soit leur éclairage (Fig. 7 b). De même le traitement des paysages est simplifié, l'usage d'un dégradé conventionnel des bleus remplacant les subtiles modulations antérieures.

L'examen des radiographies apporte encore des informations nouvelles sur les phases d'élaboration de la peinture. On décèle l'emploi fréquent d'une couche d'impression huileuse au blanc de plomb (15) posée à larges coups de brosse sur la préparation (Panneaux de Justice - Triptyque Sedano - Noces de Cana. On observe aussi, des réserves à plusieurs endroits des compositions de ces mêmes tableaux : réserve par masse pour les éléments de paysage par exemple, ou contours réservés qui cernent principalement les personnages (nombreux dans Dieu entre deux Anges. Il pourrait y avoir une relation entre l'intensité des lumières dans les modelés de G. David (carnations et vêtements rouges) et l'emploie de cette couche d'impression blanche, ainsi que entre les contours réservés des figures et l'utilisation d'un moyen mécanique de reproduction caché par un cerne. En effet, le très large cerne brun propre à la manière de G. David qui apparaît dans toutes ses oeuvres, pourrait avoir à la fois une fonction stylistique : souligner la plasticité des formes et technique, cacher les éventuels points et couvrir en surface l'espace réservé pour éviter la superposition de deux masses de couleurs. Toutefois il ne s'agit là que d'hypothèses de travail, la fonction exacte de ces deux procédés devant encore faire l'objet de recherches.

Dans les Noces de Cana on relève un dessin gravé pour les lignes de construction de la table. Comme les autres Primitifs flamands, G. David recourait donc accessoirement à ce genre de dessin. Enfin les changements de composition en cours d'exécution picturale sont abondants. Ils portent souvent sur la mise en place des yeux (Panneaux de Justice, Noces de Cana) mais aussi sur la position relative des figures, des détails de coiffe, etc ...

En conclusion, le dessin sous-jacent de G. David avait, jusqu'à ce jour, à peine retenu l'attention des historiens d'art (16). L'étude des oeuvres clés du maître en réflectographie dans l'infra-rouge est donc venu combler cette lacune. Des données nouvelles sont apparues : G. David utilise la pierre noire au même titre que Memling, il emploie le poncif dans des oeuvres de création et n'est pas asservi au dessin préfiguré qu'il corrige ou complète au moyen d'autres instruments (16). La bipolarité d'aspect de son dessin montre l'hésitation du peintre entre une écriture traditionnelle ou novatrice. Cette même hésitation se lit dans l'exécution picturale qui par son caractère encore soigné, bien que rompant avec les modelés de type eyckien, ne laisse en rien présager l'aspect très libre, et souvent désordonné du dessin sous-jacent.

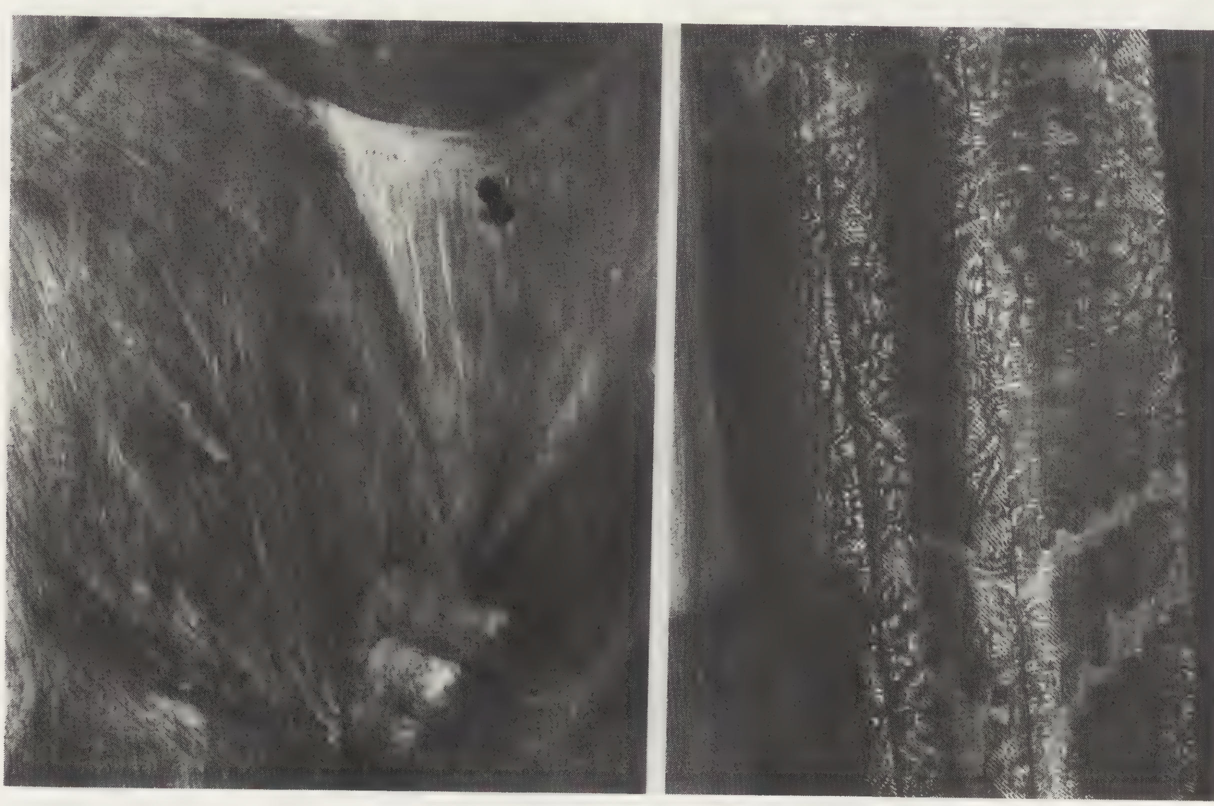

Fig. 7 a) : G. David Panneaux de Justice, détails en radiographie de la robe bleue du bourreau
b) : et du brocart du roi (Cliché Périer)

Des transformations de la structure développée par les Primitifs flamands antérieurs sont mises en oeuvre. Celles-ci, décelables en radiographie et de visu, devraient toutefois être étudiées de manière plus ponctuelle. Pour ce faire un nombre suffisant de coupes transversales devrait être réunies et leur analyse menée dans l'optique d'une recherche programmée. Seule une collaboration internationale permettrait d'atteindre cet objectif.

Les données nouvelles ajoutées à celles qui ont déjà été rassemblées permettent actuellement d'offrir une analyse affinée de la personnalité artistique de G. David; cette contribution débouchera, nous l'espérons, sur une meilleure compréhension du rôle joué par le maître dans l'évolution de la technique picturale flamande. De plus, elle fournira peut-être de nouveaux critères d'attribution.

Références

(1) C. Périer - D'Ieteren, Méthodes scientifiques d'examen à mettre en oeuvre pour améliorer les connaissances de la technique picturale des Primitifs flamands, dans Préprint du Comité pour la Conservation de l'ICOM, Ottawa, 1981 (81/1/10 - 1 à 10-7).

(2) Nous tenons à exprimer notre reconnaissance aux directeurs et conservateurs des Institutions précitées qui ont accepté de nous laisser examiner les tableaux de G. David en laboratoire. Notre gratitude va aussi aux historiens d'art, restaurateurs, physiciens et photographes pour leur collaboration active lors de l'examen des tableaux.

(3) C. Périer - D'Ieteren, La technique du dessin sous jacent des peintres flamands des XVe et XVIe siècles. Nouvelles hypothèses de travail, Colloque V du dessin sous-jacent dans la peinture, Louvain, 1983.

(4) C. Périer - D'Ieteren, La technique picturale de la peinture flamande du XVe siècle, Actes du XXIVe Congrès international d'histoire de l'art, Bologne, 1979 (paru en 1983), pp. 24 - 25.

(5) Cennino Cennini, Le Livre de l'Art ou Traité de la peinture (traduction de V. Mottez), Paris-Lille, 1891 (1ère partie, ch. XXXIV).

(6) La distinction même entre le charbon et la pierre noire ne peut se faire qu'à l'aide du microscope binoculaire, la pierre noire présentant des grains fins et arrondis, le charbon des grains anguleux et pleins d'éclats. Dans le cas des peintures les couches picturales font malheureusement obstacle à ce type d'examen. Voir à ce propos H.Kühn, Die Zeichenmaterialen des Niklaus Manuel, dans Maltecknik Restauro, 3, 1982, pp. 156 - 157 et C. Périer - D'Ieteren cf. note 3.

(7) Voir la bibliographie sur le dessin au poncif dans C. Périer - D'Ieteren, Dessin au poncif et dessin perforé. Leur utilisation dans les anciens Pays-Bas du XVe siècle, dans Bulletin de l'Institut royal du Patrimoine artistique, XX, 1984, pp. 39-46

(8) Cet aspect très différent du dessin au poncif de G. David par rapport à celui des artistes contemporains pourrait s'expliquer par le pigment utilisé. En effet, selon M. Ainsworth, les points de l'Annonciation du Metropolitan Museum seraient obtenus par dépôt d'encre noire mise à la plume ou à la brosse avec un liant aqueux. Cette donnée nouvelle serait à contrôler pour tous les dessins au poncif de G. David. Si elle se vérifiait elle poserait en d'autres termes la façon d'utiliser le moyen de reproduction mécanique. Comme il est peu probable, à notre sens, que G. David ait préfiguré son dessin par des points posés à main levée, il aurait eu recourt, comme ses prédécesseurs, à un dessin perforé mais sur lequel il aurait passé avec une brosse chargée d'encre au lieu de frapper avec une ponce (Il faudrait dans ce cas parler d'un dessin reporté plutôt que d'un dessin au poncif). D'autre part l'encre devait être fixée d'une manière ou d'une autre sinon elle risquait d'être entraînée lors de l'application de la couleur (Des expériences de reconstitution d'un dessin de ce type sont actuellement menées pour les étudiants en restauration de l'Ecole nationale des Arts visuels de la Cambre). Enfin l'hypothèse toujours avancée, d'une adhérence irrégulière d'un tracé à l'encre sur la couche d'impression huileuse mise sur la préparation se vérifie pour certains traits continus de dessin mais n'explique pas selon nous la configuration répétée de points se succédant à intervalles assez réguliers, là où nous pensons relever un dessin mécanique. A la date de remise du manuscrit cette question reste ouverte. Nous espérons que M. Ainsworth pourra nous apporter de nouvelles précisions lors de la conférence de Copenhague.

(9) Maryan Wynn ainsworth, The Technique of underdrawings. Some preliminary Observations of Works in the Metropolitan Museum of Art, dans Collogne V pour l'étude du dessin sous-jacent dans la peinture, Louvain, 1983 (à paraître en 1984).

(10) C. Périer - D'Ieteren, Colyn de Coter et les ateliers brabançons de peinture de la fin du XVe et du début du XVIe siècle (Thèse de doctorat présentée à l'Université libre de Bruxelles en 1981). A propos de la technique de Gerard David, voir aussi Martin Wyld, Ashok Roy et Alistair Smith, Gerard David's "The Virgin and Child with Saints and a Donor, dans National Gallery Technical Bulletin, vol. 3, 1979, pp. 51 - 65.

(11) La manière de distribuer les blancs et la présence ou non d'effets de facture dans l'épaisseur de la couleur permet de proposer une chronologie relative des oeuvres de G. David. Ainsi dans ses oeuvres de jeunesse telles la Nativité et le Triptyque Sedano, les charges de blanc de plomb dans les lumières restent encore très lisses. Les effets de facture commencent à apparaître dans les Panneaux de Justice, sont volontairement contenus dans Dieu entouré d'Anges et se développent ouvertement dans les Noces de Cana.

(12) P. Philippot et C. Périer - D'Ieteren, Style et technique dans la peinture flamande du XVe siècle, dans Formes, Bulletin de l'Institut d'Histoire de l'Art de Strasbourg, n° 4, automne 1982, pp. 6-7.

(13) Nous remercions M. Ainsworth de nous avoir apportés ces précisions à propos de l'Annonciation conservée au Metropolitain Museum. Les mêmes observations peuvent être formulées pour les peintures étudiées ci-dessus.

(14) C. Périer - D'Ieteren, op. cit., Bologne, 1979 (1983), p. 33.

(15) On note une relation entre le tracé du dessin et les reliefs provoqués par les stries de la brosse dans la couche d'impression; sans doute imparfaitement poncées. Sur les reliefs le trait marque davantage que dans le creux où il est même souvent interrompu. Ce type de tracés discontinus s'observe dans les dessins à la plume et à la pierre noire (Fig. 2 b).

(16) La description des techniques de dessin sous-jacent mise ici en évidence est fondée sur les résultats visuels obtenus par réflectographie infra-rouge et par différents essais de reconstitution de dessins sous-jacents. Ces derniers furent réalisés par les étudiants de la Cambre, que nous remercions vivement. Sur une préparation de craie et de colle parfaitement polie et imperméabilisée, ils ont copié des dessins de Memling, G. David et Colyn de Coter, tels que révélés par la photographie dans l'infra-rouge. Le pinceau, la plume d'oiseau et de roseau, la pierre noire et le charbon, ainsi qu'un poncif (calque perforé) frappé de noir d'os, ont été utilisés. Pour confirmer les hypothèses de travail avancées, il faudrait maintenant pouvoir procéder à des analyses de matériaux permettant de caractériser la pierre noire et le produit utilisé pour le poncif. Toutefois, comme ces analyses nécessitent des prélèvements de matière, elles nous paraissent difficiles à réaliser sur des oeuvres en bon état de conservation.

(17) Cette étude présente l'état actuel de notre recherche sur G. David. D'ici le congrès de Copenhagen, d'autres peintures seront encore examinées. De son côté, M. Ainsworth poursuit activement ses recherches sur les oeuvres conservées aux Etats-Unis. Des données nouvelles pourraient donc venir soit encore étayer les hypothèses avancées soit en infirmer certaines.

THE INTERMICROSCOPIC CORRELATION (LM, SEM) OF CROSS-SECTIONS OF WRITING MATERIALS

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SUMMARY

Correlative investigations of thin-sections and bulk cross-sections of methacrylate embedded samples of paper and parchment were done by using transmitted light microscopy (LM) and scanning electron microscopy (SEM) combined with energy dispersive x-ray spectrometry (EDS). The aim of these studies was to clarify a possible dependence between the brownish discoloration encountered in manuscripts and works of graphic art affected by "Tintenfrass" and the distribution of transition metal ions in the cross-sections of the carrier materials. There was hope to gain more information by observing the same specimen details with different microscopes. Therefore, suitable specimen positions were selected with respect to the intensity of staining of cross-sectioned particular fibres by using LM and relocated in the face of the cut off embedding blocks by using SEM where the amounts of transition metal elements were measured by EDS. Our investigations revealed a positive correlation between the intensity of staining of the carrier materials and their content of iron thus suppporting theories according to which the degradation of writing materials under the influence of irongall inks cannot be alone due to free sulfuric acid but rather take into consideration the effect of iron and other transition metal ions as powerful catalysts in the course of oxidative degradation of biopolymers such as cellulose and proteins.

1. INTRODUCTION

In the course of investigations concerning phenomena of pigment- or ink- induced damage of writing materials such as paper and parchment (Kupferfrass, Tintenfrass) it would very often be desireable to have a direct comparison between the results of different microscopic methods. Simultaneous processing of the same piece of specimen for different microscopic methods with the aim of observing identical specimen positions by light microscopy (LM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM) is already routinely employed in the field of biological research (1). In the case of damages of paper or parchment by the action of transition metal ions such as iron and copper contained in inks or pigments some hope can be placed in combining investigations of thin-sections in the transmitted light microscope (LM) with the investigation of the bulk cross-sections by means of SEM and energy dispersive x-ray spectrometry (EDS). Such a procedure can be considered to render new insights into the complex problem of "Tintenfrass" because apart from the breaking out of the writing a noticeable brownish discoloration of the paper or parchment carriers in the surrounding of the writing occurs accompanied by a decrease of their mechanical strength thus representing an early stage of the degradation process. Since a long time the possible reasons for the destructive action of irongall inks have been discussed. Some researchers prefer the formation of free sulfuric acid as an explanation for this action while others postulate that transition metal ions represent powerful catalysts in the course of oxidative reactions involving biopolymers like cellulose or proteins. It cannot be excluded that components of the inks could migrate under the influence of excessive humidity into the surrounding of the writing and it therefore seems mandatory to investigate the distribution of transition metal ions in the cross-sections of these areas. It is undoubted that SEM/EDS suits this purpose very well. A selective measurement with respect to particular fibres or specimen positions, however, will only be possible if color photomicrographs from thin-sections are at hand which have been taken from that specimen position being subsequently investigated as bulk cross-section in the SEM. On the basis of this procedure a specific correlation between the discoloration of particular fibre cross-sections as well as selected areas in the cross-sections and a possible content of transition metal ions will be facilitated. The results of our investigations described in the following should be seen as a first approach to this problem because to the best of our knowledge there are no published results concerning correlative studies in this field.

2. EXPERIMENTAL

On the basis of practical experience gained in the course of investigations concerning the degradation phenomena caused by copper-containing pigments (2) small strips of paper or parchment were specifically oriented in flat embedding moulds (Reichert, Austria) and embedded in a methacrylate-containing medium (Technovit 7100, Kulzer, FRG). The recommendations of the supplier were observed in all essential steps except the polymerization temperature. In order to achieve quicker setting a higher temperature (50^{o}C) has been used because prolonged setting times resulted in irreversible stickiness of the blocks. It should be emphasized here that the correct choice of the embedding mould can help in omitting severe difficulties due to the specimen moving out of the desired position. So the trimming of the block is made much easier. Great care should be taken in order to avoid trimming of the sample itself. Especially in the case of parchment samples the milling-head of the trimmer causes heavy tearing so that a series of sections is necessary to reach mechanically undamaged material. Sectioning of the blocks was done on a routine microtome using disposable steel knives (Histoset, Kulzer,FRG). Sections with a thickness of appr. 5 µm were taken and either transferred to the surface of a water bath kept at 40^{o} to have them stretched or mounted

directly on standard microscope glass slides. Special care has to be taken with respect to the duration of the stretching procedure because as a consequence of mechanical stress due to swelling of e.g. the paper fibres considerable portions of the sample can be lost as they will fall out of the section. Furthermore, the possibility of extraction artifacts can never be totally excluded. Considering these circumstances the sections were in nearly all of the cases mounted directly on the slides with paraffinum liquidum or immersion oil. After taking off a suitable section which was processed in the forementioned way and controlled by LM including photomicrography the tip of the specimen block was cut off parallel to the block face and mounted on specimen holders for SEM with quick setting epoxy adhesive. For the purpose of EDS coating was first done by evaporation of 20 nm carbon. For high quality photography an additional layer of 10 nm Au-Pd (40/60) was deposited by sputtering. The coated specimens were investigated in a Jeol JEM 100C/ASID 4D electron microscope with an EDX-290 x-ray microanalyzer (Link Ltd., GB) attached to. Accelerating voltage: 40 kV, Tilting angle: generally 35^{o}, Counting time: 100 sec.

3. ANALYTICAL RESULTS

The investigated samples were taken from the following objects:

1) Figurine (sketch for a costume), dated between 1848 and 1859, heavily blackened by spilled ink (Theatersammlung der Österr. Nationalbibliothek, Inv.Nr. HG 29351-76)
2) Manuscript, copy on thin paper, dated 19th century (Niedersächsische Staats- und Universitätsbibliothek)
3) Autograph, dated 1722 (Musiksammlung der Staatsbibliothek Preußischer Kulturbesitz Inv.Nr. MS 11.481)
4) Fragments from the "Black Prayer Book", parchment, dated appr. 1470 (Handschriftensammlung der Österr.Nationalbibliothek, Codex 1856)
5) Calfskin parchment no. 9, produced according to traditional prescriptions (Messrs. Carl Wildbrett, Boblingen FRG)

Large areas of the sample surface have been analyzed by EDS in order to provide a survey on the elements present in the samples. Highly damaged areas with high concentrations of ink were investigated as well as undamaged reference material. Referring to object No.4 it has to be noted that on the pages of the prayer book no writing with ink took place. The more or less uniform dark color of the pages as a whole was obviously achieved by the large-scale application of solutions of iron and copper salts under reducing conditions. Table 1 shows the results of the surface analyses (3).

The investigations of the cross-sections of the paper samples (see Table 2) show clearly that large amounts of ink being applicated lead to characteristic distributions of iron across the paper fleece. There is a distinct accumulation of iron in the middle of the fleece correlating with the observation of dark to nearly black deposition products in the LM. Simultaneously the thickness of the paper fleece increases in the damaged areas of sample no. 1 what seems to be a consequence of the abundance of reaction products (3). Generally it can be stated that whenever the paper carrier has undergone degradation iron is clearly detectable in the damaged areas. Though there are often found high concentrations of iron in particular cross-sections of fibres visible damage is not necessarily to be observed. In the LM cross-sections of fibres with high iron concentration are without exception intensively stained whereas - according to SEM/EDS measurements - more or less unstained cross-sections hve only minimal concentrations of iron or no iron at all. The lateral distribution of iron in the surrounding of the writing leads to the assumption that the climatic conditions during the storage of objects of this kind is of utmost importance. The spreading of the iron compounds is evidently caused by the action of excessive humidity. The excellent correlation between the extent of damage and the concentration of iron is clearly demonstrated by the fact that in sample areas where noticeable damage cannot be observed the iron concentration decreases extremely within the nearest surrounding of the point of application of the ink.

The investigation of sample no.4 yielded a very interesting result in the way that the staining of the parchment has obviously not been achieved by immersion of the pages in the appropriate salt solutions. The metal salt solutions were rather spread over the surface by means of a paintbrush. This conclusion can be drawn from the fact that the concentrations of iron in the middle and the undersurface of the samples are only 30% as compared to the surface concentration. Additionally, copper is only found on the surface of the samples (compare Table 2). Considering morphological aspects it has to be stated that in comparison to the fibrillar structure of untreated parchment no fibrillar structure can be observed in this heavily damaged object any more. In the course of reaction with transition metal salts (iron and copper) the fibres were obviously fused leading to a complete breakdown of the original structure. Compared to untreated parchment the thickness of the damaged samples is strongly diminished. This observation can be made by LM as well as by SEM.

In summary it can be concluded that the results of our investigations support theories according to which the degradation of writing materials under the influence of irongall inks is not necessarily due to the action of free sulfuric acid but can rather take place on the basis of metal-ion-catalyzed oxidative degradation of cellulose and proteins (4, 5).

ACKNOWLEDGEMENT

Thanks for leaving sufficient sample material are due to Institut für Restaurierung (Österr. Nationalbibliothek), Musikabteilung der Staatsbibliothek Preußischer Kulturbesitz, Mr. G. Brannahl (Niedersächsische Staats- und Universitätsbibliothek), and Messrs. Carl Wildbrett, D-8903 Bobingen, FRG.

Table 1

Net counts of the elements found in the surface of the samples under investigation

Sample no.	1		2		3		4	5
	a	b	a	b	a	b		
Al	–	–	179	–	–	–	–	–
Si	–	–	185	304	–	249	–	–
P	–	–	–	–	–	–	164	311
S	2718	–	435	484	1214	446	277	251
K	–	–	1914	348	2496	84	–	–
Ca	167	504	761	1233	1197	491	2212	1814
Fe	8199	–	3977	137	13018	–	8320	–
Cu	–	–	224 1)	–	88 1)	–	2375	–
Zn	–	–	73 1)	–	294 1)	–	–	–

a damaged, b undamaged, 1) not detectable in the cross section

Table 2

Distribution of transition metal ions in the cross-section of the samples.
I surface, II middle, III undersurface of the samples
Net counts are means (n = 4) ± standard deviation

sample no.		I	II	III	
1 D = 0.2 mm	Fe	1530 ± 320	2956 ± 695	1218 ± 433	+++
2a D = 60 μm	Fe	3239 ± 569 (writing)	4283 ± 152	2760 ± 433	++++
2b D = 80 μm	Fe	3950 ± 953 (writing)	1678 ± 480	1737 ± 320	+++
2c D = 80 μm	Fe	754 ± 243	623 ± 320	577 ± 284	++
2d D = 0.1 mm	Fe	662 ± 116	593 ± 137	315 ± 155	+
3a D = 0.1 mm	Fe	5572 ± 1020 (writing)	1849 ± 362	522 ± 269	+++
3b D = 0.1 mm	Fe	3576 ± 620 (writing)	226 ± 125	63 ± 28	0
4 D = 0.15 mm	Fe Cu	9618 ± 603 2029 ± 104	3042 ± 632 –	2797 ± 529 –	++++

D average thickness of cross-section; 0 practically undamaged; + little damage; ++ moderate damage; +++ strong damage; ++++ extremely strong damage

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TO THE APPLICATION OF ION SELECTIVE FLUORIDE ELECTRODE FOR THE CHARACTERIZATION AND RELATIVE DATING OF HUMAN BONES

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SUMMARY

Bones (skull and postcranial) from a cemetery at Abusir (1000 years B.C.) have been analysed. The results have been compared with the analysis of bones 4400 and 14000 years old. Determination of fluoride ion concentration by ion selective fluoride electrode, specific mass (density) by pycnometric method, humidity content (at 110°C), bonded water (at 180°C) and organic matter (at 550°C) in the bones have been carried out. The dependence of the fluoride concentration in bones of individuals up to circa 20-30 years is essentially linear. From the regression curve of the relation between the age and the fluoride content, the probable age of individuals can be estimated. The observed dispersion of fluoride content in studied bone samples of adults is ±29 %. The specific mass of bones increases with decreasing organic matter content. From the organic matter content in bones (from the specific mass) the state of bones can be deduced and necessary procedures for conservation and condition for deposition of bones can be inferred. A comparison of the fluoride content in bones from 1000 years B.C. with results obtained on the samples 4400 years and 14000 years old proved the relative dating of "young" bones should be carried out very cautiously with respect to the large range of fluoride content.

INTRODUCTION

The analysis of human bones obtained by archaeological excavations using absolute and relative dating, evaluation of the decomposition state caused by posthumous factors and determination of age and sex presents a very serious problem which has not been solved satisfactorily in extent up to this time. Naturally, the choice of suitable conservation and petrification of human bones method depends on the state of decomposition, too. Several analytical physical, physico-chemical and chemical methods have been used for this evaluation /TITE 1972, GOFFER 1980, RIEDERER 1981/. The methods used contribute to more objective classification of studied materials, however a set of external and internal factors causes errors which are necessary to be respected. Various correction factors have been used to minimize these negative effects. The relative bone dating using the fluoride content determination is one of the oldest analytical methods applied for this purpose already in the past century. The accuracy and the rapidity of applied analytical methods have played always an important role. In the first place, two methods are used for the determination of fluorides at present - ion selective fluoride electrode /e.g. SINGER, ARMSTRONG 1968/ and neutron activation analysis /EISENBARTH, HILLE 1977/. X-ray diffraction analysis /e.g. BAUD 1960/ and infrared spectroscopy /e.g. FREUND, KNOBEL 1977, OKAZAKI 1983/ might suggest certain possibilities.

The aim of this paper is to correlate the fluoride content with specific mass, humidity, bonded water and organic matter contents in human bones. This correlation enables not only the relative dating of human bones from the same locality, but also the evaluation of the state of their posthumous decomposition, their possible destroying during deposition in museums and the choice of appropriate conservation process. The application of X-ray diffraction analysis and infrared spectroscopy is in progress. The main part of the material studied forms the human bones from a cemetery at Abusir by Cairo has been generated in the 10th century B.C. (F1-F27, checked by the radiocarbon method /STROUHAL, BAREŠ - in press/). Two samples of the same locality (24th century B.C., F28, F29) and one sample from Wadi Halfa (14000 years old, F30) were used for comparison. All materials studied were bone samples of a skull or a postcranial.

EXPERIMENTAL

Determination of fluoride ions in bones

The determination of the concentration of fluoride ions in bones was carried out by the use of Fluoride meter Radelkis, type OP-108 with the ion selective fluoride electrode OP-F 7111D and the reference silverchloride electrode OP-0820-P using a modified method after Singer and Armstrong /SINGER, ARMSTRONG 1968/.

Standard solutions

For calibration of the fluoride electrode, standard fluoride solution Radelkis, type S-F-01 (concentration 10^{-1}M NaF, pH = 7.10±0.05) was used. Further standard solutions (10^{-2} - 10^{-6}M NaF) were made by dillution of Radelkis standard solution with distilled water. As a buffer, TISAB solution prepared after Orion research analytical methods guide (9th ed., December 1978, p.34) was used.

Preparation of bone samples (F1-F8, F30 skulls, F9-F29 postcranials)

The samples of bones were ashed at 550°C for six hours. The ash was dissolved by addition of 1M HCl and neutralized by addition of 0.5M NaOH.

Procedures

Because of expected values of fluoride ion content about 10^{-3} - 10^{-4}, the fluoride electrode was calibrated by the solution containing 10^{-3}MF^-. Samples and standards were kept approximately at the same temperature. The bone ash obtained by calcination of circa 120 mg of bone was dissolved in 5 ml 1M HCl, neutralized by addition of 5.5 ml 0.5M NaOH and filled up to 25 ml (20°C) with distilled water. 5 ml TISAB solution was added to 5 ml of such obtained solution. Both electrodes were inserted into the solution which was stirred until a constant reading of pF was obtained. This lasted 5 to 15 minutes. All determinations were repeated threetimes.

Determination of humidity, bonded water and organic matter

Experiences first of all the temperature conditions obtained by Kiszely on thermal analysis of human bones have been applied in

our analytical work /KISZELY 1969, KISZELY, DAVID 1969/. The bone humidity and the water content bonded in bones were determined by drying the samples at 110 and 180°C resp. for 5 hours with the weight of samples circa 120 mg. The organic matter content was calculated from the weight loss of samples heated at 550°C for 6 hours.

Determination of specific mass
The determination of bone specific mass was realized by use of the pycnometric method. The bone samples (50-60 mg) were heated in pycnometers partly filled with distilled water at about 70-90°C. The air from bone samples was removed by shaking of pycnometers under simultaneous moderate evacuation in a desiccator. After tempering at 22-23°C and filling up the pycnometers with distilled water, measurements were carried out (twice for each sample) and the specific mass was calculated.

RESULTS AND DISCUSSION

The bone composition changes not only in live but also in necroitic organism. Chemical and mineralogical studies of recent and fossil bones enable to explain changes running in bones during fossilization /HASSAN 1976, HASSAN et al. 1977/. From the fluoride analysis point of view, the inorganic bone component - apatite phase is very important in which fluorine as fluoride is bonded. In agreement with published data /e.g. JACKSON, WIEDMANN 1959, GABOVICH, OVRUTSKIY 1977/, the fluoride content in recent bones depends on age, amount of fluorine present in drinking water and on food composition, too (e.g. tea may be a possible source of fluorine). The fluoride content is higher in spongy bones than in compact bones, it differs also in various human bones. During gradual fossilization, further factors as time of bone deposition in soil, composition of soil and underground water may influence the posthumous degradation of bone components including the ion changes (esp. Ca^{2+}, CO_3^{2-}, F^-) of bones and neighbouring soils and water (neighbouring environment). The apatite bone structure is enriched in fluoride ions, and its structure gradually changes from dahllite (carbonate hydroxoapatite with less than 1 % F) to francolite (carbonate hydroxoapatite with more than 1 % F^-) and theoretically up to fluorapatite containing 3.8 % F^- /HASSAN 1976, HASSAN et al. 1977/. In a recent paper /ANNAPOORNA, RAO 1981/ authors have assumed that the probability of the fluoride release from bones deposited under natural condition is greater than their absorption. Therefore, the fluoride concentration in bones cannot be used for relative dating of bones. Unfortunately the original paper has not been available. Thus, we were not able to view the results. In addition to the fluoride content, further analytical data as specific mass, water and nitrogen content etc. may be used for the classification of bones /COOK 1960/. We determined the specific mass, humidity (at 110°C), bonded water (at 180°C) and organic matter content (at 550°C). The results are given in tables I, II and figures 1, 2.

These main results of the interpretation of experimental data are as follows:
1. The fluoride content in bones approximately from the same period and the same locality increases with the age. At Abusir, one can suppose constant fluoride concentration in drinking water (water from river Nile was consumed). A relatively small dispersion of fluoride content was observed in bones of persons up to 20-30 years of age. As can be derived from the regression curve, the dependence of fluoride content with age in the given life interval is practically linear. The change of the angular coefficient of the straight line will depend on absolute bone age and locality conditions. For older individuals approximately over 30 years of age, the rate of increase of the fluoride content lessens until a plateau is reached. The dispersion of fluoride content is, however, rather substantial (in the interval 26-50 years of age - after anthropological classification - that means for adults) the fluoride content varies incidently from 0.077 to 0.227 mass %, $\emptyset$ = 0.160 mass %, σ = $\pm$0.047 mass %, that is $\pm$29 %. Nevertheless from the observed data can be inferred that for the same locality using the regression curve based on experimental analytical results for the interval 0-30 years of age the approximately age of individuals can be determined and so e.g. the classical age determination by use of teeth can be checked or completed. The problem of fluoride content decrease observed in recent bones of older or old individuals and its dependence on age and sex remains still open. No dependence of the fluoride content on humidity, bonded water and organic matter contents in bones nor the specific mass of bones was observed for such sets of relatively young bones (1000 years B.C.). From further analyses of bones which are in progress, one can assume that these factors are manifested significantly on older bones, e.g. a bone sample from Wadi Halfa, 14000 years old. The fluoride content in spongy and compact bones was compared. In agreement with the data from analysis of the recent bones /e.g. GABOVICH et al. 1977/ spongy bones contain more fluoride ions than compact bones - in our analysed samples more than twice. The fluoride content in various bones of the same individuals differs as follows from the Gabovich´s observations /GABOVICH et al. 1977/. Therefore it is very important and very necessary to analyse and to compare the same bones from various individuals, which is difficult to preform esp. in the case of human bones from ancient Egypt. We analysed samples of skulls (F1-F8, F30) and of postcranials (F9-F29). The comparison of bone samples from the cemetery at Abusir by Cairo (1000 years B.C. F1-F27, 2400 years B.C. F28, F29) and bone sample from Wadi Halfa (12000 years B.C. F30) prove the following dependence of fluoride content on age:

1000 years B.C.	$\emptyset$ 0.124 $\pm$ 0.061 mass % F^- (all individuals)
	$\emptyset$ 0.160 $\pm$ 0.048 mass % F^- (adults only)
2400 years B.C.	$\emptyset$ 0.166 $\pm$ 0.012 mass % F^- (adults)
12000 years B.C.	$\emptyset$ 2.790 $\pm$ 0.067 mass % F^- (adult)

This comparison indicated a possibility of relative dating, however, it is evident, that the resolving power depends on absolute bone age. The older the bones are, the higher probability of the correctness of their relative comparison is. In the main the fluoride content in bones 2000-3000 years old is consistent with the values found in recent bones.

2. Mass decreases of bones at 110°C (mostly humidity) vary in the range 4.06-9.07 mass %, $\emptyset$ = 6.7 mass %, σ = $\pm$1.44 mass %, that is $\pm$21.5 %. Mass decreases at 180°C (essentially bonded water, humidity excluded) vary in the range 0.79-3.15 mass %, $\emptyset$ = 1.4 mass %, σ = $\pm$0.45 mass %, that is $\pm$32 %. Probably the release of humidity and bonded water may

Table I: The dependence of fluoride ion content on age of individuals

1	2	3	4
±2	0.027	0.029	24
2-3	0.058	0.061	1
4-5	0.053	0.057	23
8-9	0.057	0.063	18
±9	0.054	0.058	14
9-10	0.064	0.070	17
10-11	0.046	0.049	3
14-16	0.066	0.070	2
±16	0.104	0.113	15
16-18	0.115	0.120	5
25-30	0.107	0.111	8
25-30	0.209	0.221	26
28-32	0.095	0.101	19
28-32	0.112	0.123	25
25-35	0.169	0.179	4
30-40	0.117	0.126	10
20-50	0.147	0.157	20
30-40	0.178	0.190	29
30-40	0.196	0.212	13
35-45	0.145	0.155	7
35-45	0.201	0.218	27
35-45	0.227	0.243	21
40-50	0.064	0.070	16
40-50	0.140	0.150	6
40-50	0.144	0.157	22
40-50	0.155	0.165	28
45-55	0.201	0.216	9
adult	0.213	0.225	12
adult	0.217	0.230	11
adult	2.790	2.853	30

1. Age of individuals (anthropological determination); 2. Fluoride ion content (original bone) /mass %/; 3. Fluoride ion content (after heating at 110°C) /mass %/; 4. Sample No

Table II: Results of the determination of humidity, bonded water, loss by ignition and specific mass

1	2	3	4	5	6
11.4	2.21	2.23	1.41	7.76	30
12.3	2.60	5.95	1.02	5.33	20
12.5	2.72	4.03	0.80	7.67	8
12.6	2.65	6.16	0.81	3.29	19
13.1	2.59	6.67	1.27	5.16	23
13.2	2.64	4.06	1.09	8.05	1
13.3	2.54	5.80	1.14	6.36	26
13.9	2.48	8.17	1.29	4.44	24
14.6	2.51	7.04	1.43	6.13	21
15.0	2.46	8.67	1.54	4.69	17
15.2	2.47	8.22	1.49	5.49	27
15.5	2.46	6.35	1.93	7.22	29
15.3	2.47	5.37	0.79	9.14	3
15.8	2.47	7.66	1.43	6.71	13
16.1	2.37	8.73	1.36	6.01	25
16.2	2.48	8.12	0.87	7.21	22
16.2	2.52	8.43	1.64	6.13	15
16.7	2.56	5.40	0.99	10.41	11
17.0	2.46	9.07	1.66	6.27	18
17.1	2.51	7.84	1.64	7.62	14
17.2	2.49	5.32	1.66	10.22	12
18.0	2.59	7.87	1.71	8.32	16
18.4	2.58	4.23	1.47	12.70	5
25.0	2.22	5.56	1.15	18.29	4
26.0	2.27	6.33	1.65	18.02	2
27.1	2.18	6.56	2.19	18.35	28
32.0	2.14	6.48	1.84	23.68	6
32.4	2.10	6.53	1.63	24.24	7
32.4	2.19	7.01	1.51	23.88	9
33.7	2.12	6.82	1.71	25.07	10

1. Loss by ignition at 550°C /mass %/; 2. Specific mass /g.cm^{-3}/; 3. Humidity /mass %/; 4. Bonded water (mass decrease at 180°C recalculated to mass decrease at 110°C) /mass %/; 5. Organic matter (mass decrease at 550°C recalculated to mass decrease at 180°C) /mass %/; 6. Sample No

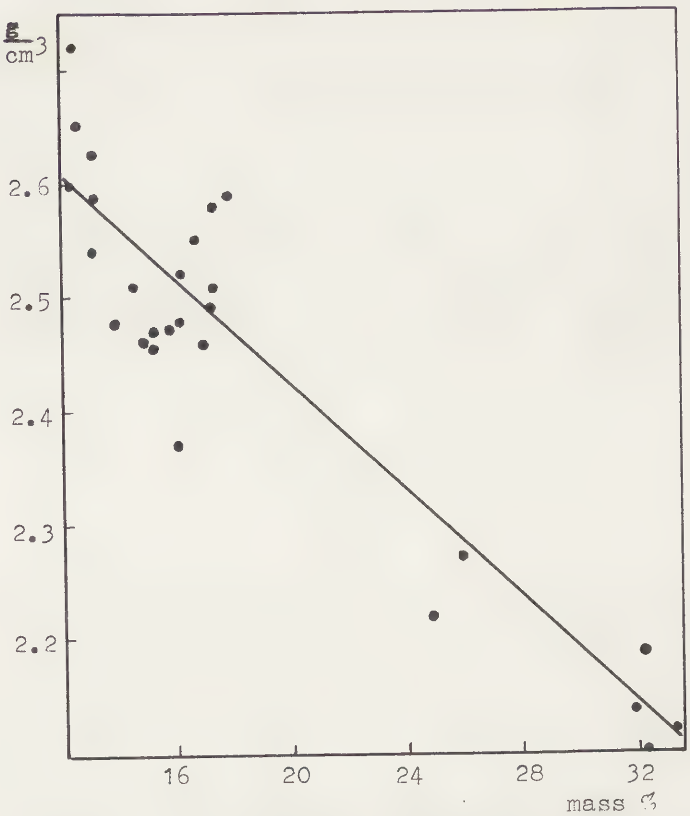

Fig. 1 The dependence of specific mass on loss by ignition (at 550°C)

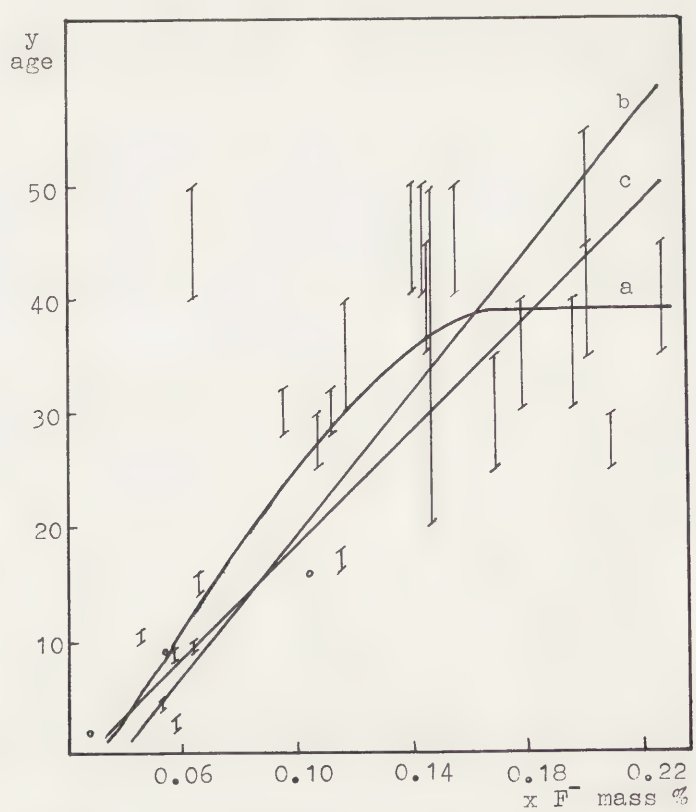

Fig. 2 The dependence of age of individuals on fluoride ion content

a) samples F1-F25 (F16 omitted) $y=-19.28+0.611x-159.10^{-5}x^2$

b) samples F1-F25 (F16 omitted) $y=-11.67+0.310x$

c) samples F1-F19 $y=-6.81+0.253x$

be partly overlapped. No dependence on age of individuals and fluoride content in bones was found.

3. Mass decreases of bones at 550°C (essentially organic matter, humidity and bonded water were subtracted) manifest the most expressive dispersion in the range 3.29 - 25.07 mass %, $\emptyset$ = 10.4 mass %, $\sigma = \pm 6.74$ mass %, that is ± 64.8 %. This fact indicates that at the same cemetery the rate of the decomposition of bones may vary (esp. the successive decrease of organic matter). It is not possible, however, to exclude that the bones containing more organic matter could be "younger" (relatively younger) without remarkable difference in the fluoride content. This assumed age difference, however, cannot be too essential. The amount of organic matter in bones does not show any dependence on the age of individuals.

4. An evident dependence of specific mass on mass decrease at 550°C or organic matter of bones was observed. The more organic matter the bones contains, the lower is its specific mass and vice versa. The data characterize substantially the present state of bones which may give an orientation for correct deposition conditions and necessary conservation procedure for bones. The more organic matter a bone contains, the lower is its resistance to outer environment, disposition for attack of various microbial pests increases etc. The definition of necessary climatic conditions (esp. temperature and relative air humidity, light intensity) in such cases seems to be entirely indispensable.

The analysis of experimental data obtained up to date shows the complex character of the problem, however, partial positive results confirm the necessity in continuation of similar investigations. The X-ray diffraction analysis and infrared spectroscopy study of bones are in progress and the results will be correlated with chemical analysis presented in this paper. The human and animal bone samples from longer chronological periods will be studied.

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A PHOTOGRAPHIC METHOD FOR DETECTING THE OXIDATION OF MATERIALS

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SUMMARY

Oxidation of materials at room temperature releases hydrogen peroxide which can produce an image on a specially prepared photographic film. The technique can be used to follow the rate of deterioration of materials, test storage materials for photographs, detect watermarks and to detect recent scratches on certain metals. It will also detect certain additions and local treatments to art works.

INTRODUCTION

In the early days of photography it was discovered that light was not the only factor which could cause images to be produced on photographic plates. In 1842 Moser (1) noticed that certain bodies were capable of altering a silver iodide plate in the dark. The plate was darkest where the "action of the body was strongest". Moser assumed that some bodies were self luminous. In 1896 Henri Becquerel discovered radioactivity because certain substances could form an image on a photographic plate in the dark, even when the substances were separated from the plate by black paper. While conducting research on radioactivity William J Russell rediscovered Moser's effect with non-radioactive substances and continued his work for several years. Russell became famous for his work and what once was the Moser Effect is now often called the Russell Effect. Russell published a series of papers in the Journal of the Royal Society (2).

Russell found that several types of material could produce images. The metals; zinc, aluminium, magnesium and cadmium were particularly good, especially if the surface had been freshly abraded. He found that during his experiments, the photographic film was not exposed by the action of light but by a chemical species. Further work showed that hydrogen peroxide could produce the effect and Russell concluded that oxidation of the metal produced hydrogen peroxide which affected the film.

Organic materials are also capable of forming images and Russell found that wood, leaves, paper, paints and certain oils were particularly active. We can reinterprete Russell's results in the light of present day knowledge and can show that materials which affect photographic plates are those which oxidise slowly at room temperature (autoxidise).

Autoxidation is now known to be one of the most important mechanisms for the non-biological deterioration of organic materials. However, this mechanism has received little attention in conservation circles but see Gratton (3). In industry and in the universities, autoxidation research has shown that the mechanism involves free radicals, and that peroxides are involved at many stages of the reaction. Hydrogen peroxide can thus be produced during autoxidation. For the remainder of this article it will be assumed that hydrogen peroxide is responsible for the Russell Effect, however, there is a possibility that other species may be additionally or alternatively responsible; these include electrons, peroxide free radicals and singlet oxygen. Autoxidation is known to be accompanied by light emmission (3) but this is not the mechanism for film exposure as a piece of silica glass transparent over the Ultra-violet/visible range (200-800 mm) blocks all activity.

PREPARATION OF FILM

While early workers, including Russell, were able to use commercially available photographic film, modern films are unsuitable because they are purposely made to be stable in normal storage environments. Film for the present research work was prepared using a method devised at the Kodak Research Laboratory (UK) by Clifford (4). A sheet of Kodak reproduction film (type 2566) is immersed in 0.05M ammonium hydroxide for four minutes and allowed to dry. The process can be performed in a darkroom with Kodak 6B safelight illumination. Drying of the film takes a few hours and this is done in a light tight box.

To obtain a Russell image, objects are placed in direct contact with film overnight. An x-ray cassette is often a useful container. The film is finally developed using conventional fixer and developer, in this case Ilford Phenisol and Hypam respectively - each diluted to 20% $^{v}/v$ of the stock concentration. Freshly prepared film of most kinds are highly sensitive to hydrogen peroxide and in the sensitisation process described ammonia bathing produces a fresh surface to the silver halide grains as well as increasing the grain size thus producing a very sensitive film.

ABRADED METALS AND DETECTION OF WATER METALS

Metals which display the Russell Effect will do so when their surfaces are freshly exposed, for example, when they have been freshly abraded or scratched. (Fig 1)

Fig 1. Russell photograph of a sheet of aluminium that has been scratched and abraded.

Aluminium oxidises rapidly and the ability to affect a photographic plate wears off in a few days. Zinc oxidises more slowly and a freshly abraded piece of this metal remains active for several months. A uniformly abraded flat piece of metal may act as a source of hydrogen peroxide and can be used to detect watermarks.

If a piece of paper is placed between a sheet of sensitised film and a sheet of prepared metal the hydrogen peroxide evolved from the metal will pass through the paper to the film. The passage of peroxide will be attenuated differently by the various thicknesses and densities of the paper and thus, a watermark can be revealed. Printing ink will also be faintly visible. Using this method on a Bank of England £5 note shows a watermark of equal quality to that produced by beta-radiography.

THE RATE OF DETERIORATION OF ORGANIC MATERIALS

Museum collections hold a variety of organic materials which autoxidise. One of the most important of these is paper which is composed mainly of cellulose and lignin. These two constituents are also found in many other vegetable products et textiles, fibres and wood. (Fig 2)

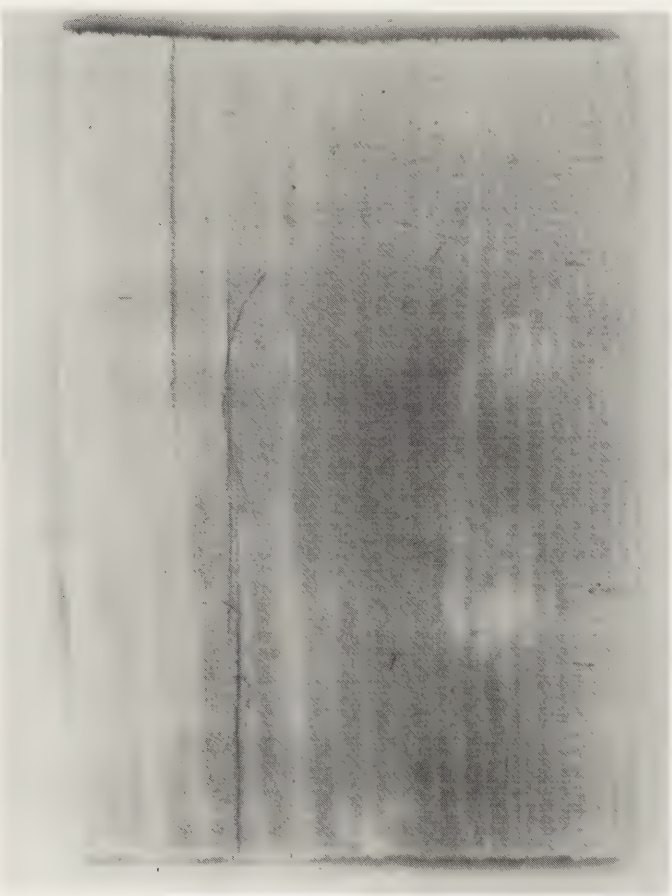

Fig 2. Russell photograph of a piece of wood.

On long exposure to light the above materials became weak due to chemical degradation. The acceleration of degradation by light is easily demonstrated using the Russell Effect.

If a piece of paper stored in darkness is partially covered with an opaque material and exposed to light for a few minutes, its Russell photograph will reveal that accelerated degradation is taking place in the light exposed area. The degradation process is photo-oxidation which proceeds by an almost identical route to autoxidation producing peroxides in the same way.

Any aqueous chemical treatment causes a change in the degradation rate of paper. It has been found that residual chemicals retain their influence on the rate of oxidation of the paper for at least a year. Areas of local application are easily detected. This may have uses in forensic examination of documents.

It is hoped that this technique will prove valuable for studying the usefulness of conservation treatments aimed at stabilising paper against degradation. Oxidation is, of course, not the only mechanism which occurs on aging; others such as acid hydrolysis must be taken into account. For example, aluminium, sulphate (alum) appears to have an excellent stabilising effect to oxidation on paper but it is well known that brittleness is brought about in accelerated aging tests due to the low pH. Oxidation is, however, an important mechanism and the Russell Effect enables the degradation rate to be examined without the need to perform accelerated tests in unrealistic conditions. The results, so far, suggest that sodium bicarbonate is a good stabilising chemical for paper, being effective against both oxidation and excess acidity. The result for aluminium sulphate is parallelled in the results obtained with leathers. Alum-tawed pigskin, which is known to be a very stable type of skin product, shows its oxidation rates to be lower than that of many conventionally tanned materials. It is probable that oxidation is an important factor in leather degradation. Most of the conventional tanning agents are known to have antioxidant properties.

The effects of light and water on paper are proving more complex that they at first appeared. These must be properly understood before proceeding with research into the stabilising effects of chemical solutions.

TESTING MATERIALS FOR PHOTOGRAPH STORAGE

McCamy and Pope (5) have established that the presence of hydrogen peroxide and hydrogen sulphide are the two most important factors in the degradation of the image on microfilm. These gases react with the silver granules which make up the image, and microblemishes occur. The same mechanism causes deterioration of black and white photographic prints and negatives. There is an exact correlation between the substances McCamy and Pope report as giving off hydrogen peroxide and those that produce a strong Russell Effect.

The Russell Effect is of use in detecting materials potentially harmful to photographs because of their hydrogen peroxide evolution. Samples of storage materials are easily ranked in order of suitability. As light can accelerate degradation of the samples they should be stored in darkness for a few days prior to testing. Good quality mounting board is generally satisfactory, but low quality lignin containing materials are unsuitable. Materials can be tested for hydrogen sulphide evolution by the conventional methods eg (6).

MISCELLANEOUS USES

Russell photographs of objects can produce unexpected results. Old oil paintings show that the surface of the paint is inactive, but the cracks in the surface of the painting (craquelure) show up very well because of the more rapid oxidation of the materials at the bottom of the cracks. Recently applied oil paint additions show up very well because of the initial rapid oxidation which takes place. Some types of paint retain this activity for several years, others for a few weeks. (Fig 3)

Figure 3. A Russell photograph of the surface of an oil painting. The dark lines and spots are defects in the paint surface.

Burmese palm leaf has a flat sandwich structure of a cellular centre covered with two relatively solid outer sheets. Manuscripts can be made from this leaf by writing on it using a steel stylus which pierces the outer layer. This writing is often difficult to read but it can be rendered easily visible using the Russell Effect as the centre oxidises much faster than the outer leaves and the writing shows up in clear black lines on the film.

Many modern synthetic resins have a high oxidation rate and areas of recent restoration on objects eg metal and stone are easily detectable. Possible uses for this mode of application include authenticity and conservation research eg depth of penetration of consolidants.

ACKNOWLEDGEMENTS

I would like to thank Dr M S Tite and Mr W A Oddy for permission to publish.

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L'APPORT DE L'EMISSIOGRAPHIE DANS L'ETUDE DES PEINTURES ET DES EMAUX

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SOMAIRE

La radiographie par réflexion ou émissiographie permet d'obtenir l'image de la couche picturale d'un tableau peint sur bois, recto-verso, ou sur métal... lorsque l'opacité du support rend illisibles les clichés par transmission. Les images résultent de l'émission d'électrons par la surface peinte irradiée avec des rayons X (> 220 kV), l'intensité de l'émission étant fonction de la composition atomique des pigments. Les émissiographies, ne laissant pas apparaître l'image du support, montrent la surface picturale, son état de conservation et les modifications éventuelles apportées à la composition.
Appliquée à l'étude des émaux, cette méthode met en évidence la technique de fabrication et oriente les recherches d'analyse des matériaux.

La radiographie par transmission, habituellement utilisée pour étudier les peintures, ne donne pas toujours des images interprétables lorsque les tableaux sont peints sur bois, épais, parquetés, exécutés recto-verso, sur métal ou sur une toile dont le rentoilage est opaque aux rayons X. L'image du support, alors prépondérante, nuit à la visibilité de la couche picturale.

La radiographie par réflexion ou émissiographie procède par émission d'électrons de la surface peinte. Elle restitue uniquement l'image de la couche picturale, celle du support n'apparaissant pas sur le film. Les densités des clichés sont inverses de celles des images radiographiques obtenues par transmission.

TECHNIQUE

Elle consiste à irradier le tableau avec un rayonnement X dur et recueillir, sur film sensible placé au contact de la couche picturale, l'image produite par les électrons émanant des différents pigments (fig. 1).

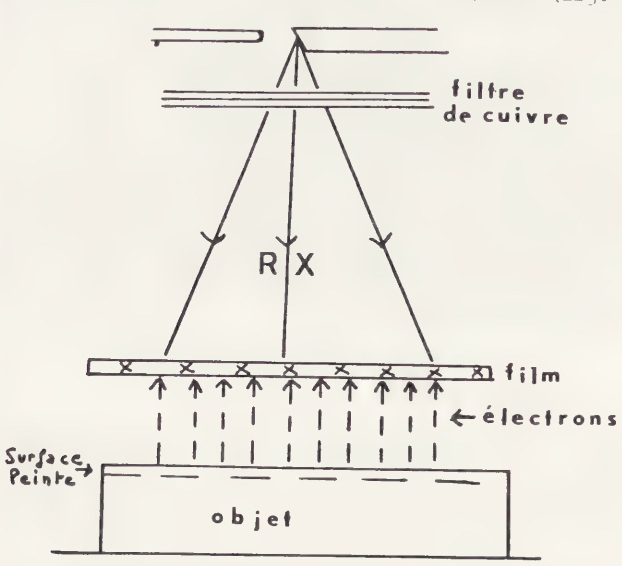

Figure 1 : Emissiographie - principe de la méthode

L'intensité des électrons résultant de l'effet photoélectrique du rayonnement X avec la matière est proportionnelle au numéro atomique des éléments émetteurs.
Les zones de plus grand noircissement du film correspondent à priori aux émissions des éléments de numéro atomique élevé. L'énergie des photons doit être supérieure à 220 kV pour que la production des électrons puisse impressionner favorablement le film radiographique. Ce rayonnement primaire comporte une part de rayonnement mou nuisible qu'il est nécessaire d'éliminer au niveau du tube par un filtre de 7 à 10 mm de cuivre.
Les films radiographiques utilisés sont à grains fins, de préférence monocouche (type médical ou industriel), l'image étant uniquement produite sur la face sensible du film placée en contact étroit avec la surface étudiée. Ce contact film-couche picturale doit être très étroit : la diffusion des électrons au sein des matériaux et leur absorption par l'air diminuent en effet la définition de l'image. Un film bicouches peut éventuellement être utilisé à condition d'éliminer après développement la face supérieure du film formant un voile sombre inutile.

Les temps de pose sont de 3 à 12 minutes pour les films monocouche, et de 1 minute environ pour les films bicouches avec une intensité de 10 mA et un kilovoltage de 220 à 270 kV. La distance source-film convenable est de 1 à 1.20 mètre selon le format du film. Les clichés peuvent être tirés sur film ou sur papier pour obtenir des négatifs comparables aux images par transmission.

Les possibilités offertes par cette technique permettent :
- dans l'étude des peintures, de
  . visualiser les couches picturales superficielles, éventuellement les transformations, l'état de conservation de surface, manques et restaurations
  . dissocier des compositions superposées en comparant l'émissiographie et la radiographie
- dans l'étude des émaux (sur cuivre ou autre métal), de
  . distinguer émaux alcalins et émaux au plomb
  . constater des différences d'émission entre émaux de même couleur
  . révéler le dessin préparatoire (ciselé, gravé)
  . orienter les analyses à effectuer sur les couches émaillées

APPLICATIONS

Peinture sur soie

"Pélerin accompagné d'un tigre" - Touen Houang - fin IXe siècle - E.O. 1141, musée Guimet (1)
H : 82 cm - L : 55 cm

La peinture est collée sur papier collé lui-même sur contre-plaqué. La composition aux couleurs profondes, rehaussées d'or représente un moine somptueusement vêtu, portant une robe rose et un manteau orné d'un quadrillage doré pointillés de blanc. Le tigre est finement dessiné et les contours de l'ensemble du sujet sont bien marqués.

La radiographie, et même la stratigraphie (fig. 2) réalisée en vue d'éliminer l'image du support, ne permet aucune interprétation, les lattes de bois du contre-plaqué formant une opacité importante et irrégulière.

La radiographie par émission d'électrons (fig. 3) donne, par contre, une image satisfaisante de la surface picturale. La plus grande partie de la polychromie apparait, le graphisme est net et précis.
L'intensité de l'émission correspond à l'emploi de pigments minéraux de numéro atomique élevé. La répartition des zones d'émission des plages colorées correspond à un noircissement plus ou moins sombre sur le film.
D'après les clichés des analyses ont été effectuées directement sur la peinture par microfluorescence X. Les émissions les plus intenses correspondent aux parties exécutées en vermillon et en minium (chasse-mouche, lèvres du pélerin, fleur et oeil du tigre). De même, le vêtement rose et son décor en croisillons pointillés, les contours des rubans du manteau, le nuage ondulant sortant de la hotte, le cartouche rose, peints avec des pigments à base de blanc de plomb, donnent des images particulièrement nettes. Les tons bruns, faits à partir de terre brûlée, n'apparaissent pas sur le film.
Les altérations et les restaurations modifiant l'état

de surface sont également visibles.

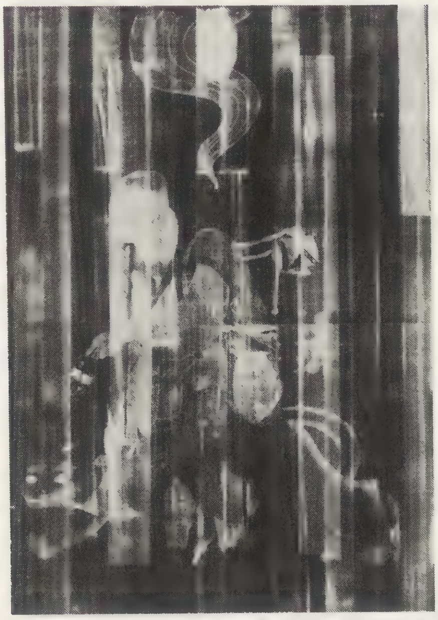

Figure 2 : Peinture sur soie
"Pélerin accompagné d'un tigre"
Touen Houang - fin IXe siècle - Musée Guimet
Stratigraphie

Figure 3 : Peinture sur soie
"Pélerin accompagné d'un tigre"
Touen Houang - fin IXe siècle - Musée Guimet
Emissiographie

Peinture sur cuivre

J.S. CHARDIN - "Femme occupée à cacheter une lettre"
XVIIIe siècle - MNR 60, musée du Louvre (?)
H : 26 cm - L : 25,5 cm

La radiographie par transmission (fig. 4) ne montre qu'une image succinte et diffuse des couches picturales : les zones denses du tableau traitées au blanc de plomb et au vermillon. Le métal forme sur le cliché une opacité prépondérante et hétérogène correspondant à la mise en forme du support par martelage. Les plages plus ou moins denses évoquent les marques de l'outil.

Figure 4 : Peinture sur cuivre
J.S. CHARDIN "Femme occupée à cacheter une lettre"
XVIIIe siècle - Musée du Louvre
Radiographie

Par contre, l'image émissiographique (fig. 5) donne une bonne image de l'ensemble de la composition. Le modelé des visages, les détails des vêtements et des tissus, sont rendus avec précision. Le contraste des rayures du manteau de la femme est très marqué, le blanc de plomb et le bleu de Prusse ayant été utilisés en alternance pour traiter les tissus.
Les plis de la tenture et l'embrasse en passementerie sont plus apparents sur le cliché que sur l'oeuvre achevée. Le repli du manteau sur le fauteuil parait avoir été modifié. Des altérations de surface apparaissent à plusieurs endroits notamment aux bords supérieur et inférieur du tableau.

Figure 5 : Peinture sur cuivre
J.S. CHARDIN - "Femme occupée à cacheter une lettre"
XVIIIe siècle - MNR 60, musée du Louvre
Emissiographie

Email sur cuivre

"Plaque émaillée représentant Geoffroy le Bel Plantagenêt, Comte d'Anjou et du Maine, duc de Normandie"
Musée Tessé - Le Mans
H : 66 cm - L : 33 cm

Cette plaque médiévale champlevée, un des plus célèbres témoignages de l'émaillerie du XIIe siècle, est constituée par une plaque de cuivre doré, émaillée et rehaussée de vernis brun.

L'étude scientifique de cet objet précieux a été réalisée par plusieurs techniques non-destructives (3), dont la radiographie et l'émissiographie. Ces techniques complémentaires, apportent des précisions sur la technique de fabrication de l'émail, celle des décors. Elles ont orienté les analyses élémentaires effectuées directement sur la surface de l'oeuvre.

La radiographie par transmission (fig. 6) montre l'image globale de l'objet : support métallique, émail et décors.
Elle a permis de :
- constater les différences d'épaisseur de la plaque de métal,
- délimiter les parties champlevées, alvéoles destinées à recevoir l'émaillage,
- suivre le tracé du dessin préparatoire et dissocier la main du maître de celle du compagnon,
- localiser des différences d'opacité de l'émail,
- situer les champs réservés correspondant aux emplacements recouverts de vernis brun.

Figure 6 : Email sur cuivre
"Plaque émaillée représentant Geoffroy le Bel Plantagenêt, Comte d'Anjou et du Maine, duc de Normandie"
Musée Tessé - Le Mans
Radiographie

L'émissiographie (fig. 7) donne une image plus détaillée de l'émaillage et des décors :
- elle restitue de façon moins régulière le dessin préparatoire mais le tracé apparent situe les traces d'or demeurant dans les cavités du dessin,
- permet de distinguer des différences entre les émaux des liserés verts séparant les fleurons à droite et à gauche du visage. L'analyse a montré une teneur en plomb plus grande là où l'émission était plus importante,
- les émaux colorés du dais architectural et des tours de la partie supérieure, non discernables sur la radiographie, sont parfaitement visibles. Les images les plus foncées correspondent aux colorations des verres par l'oxyde d'antimoine et l'oxyde de plomb constatées par l'analyse,
- les parties réservées couvertes de vernis brun : léopards, galons, fleurons du vêtement possèdent un décor gravé, vernissé et doré qui est restitué avec toute la précision d'exécution. La finesse du trait et des détails est accentuée par les restes de dorure subsistant dans le tracé,
- des différences de facture dans la réalisation des motifs du vêtement sont également apparentes. Elles soulignent les variations de qualité du décor.

Figure 7 : "Plaque émaillée représentant Geoffroy le Bel Plantagenêt, Comte d'Anjou et du Maine, duc de Normandie"
Musée Tessé - Le Mans
Emissiographie

L'émissiographie, technique non-destructive par excellence et peu utilisée en conservation, mériterait d'être plus étroitement associée aux examens radiographiques. En effet, l'image obtenue correspond à l'état superficiel des oeuvres, alors que la radiographie, opérant par transmission, donne leur constitution interne.

Les exemples exposés, témoignent de la diversité des applications possibles dans le domaine des objets d'art.

Le développement actuel du traitement de l'image pourrait permettre d'associer plus étroitement les diverses méthodes d'examen.

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L'EXAMEN RADIOGRAPHIQUE DE SCULPTURES EN CIRE DU XVIe AU XIXe SIECLE

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RESUME

Les sculptures en cire représentent par la nature de leur matériau constitutif de rares témoignages de la statuaire en ronde-bosse.
Elles se composent d'oeuvres préparatoires, destinées à être transposées dans un autre matériau, mais aussi d'oeuvres définitives. Moulées ou modelées, elles sont le résultat de procédés souvent complexes.
Les techniques de fabrication ne peuvent être déterminées par l'étude visuelle. Par contre, la radiographie permet de discerner la constitution et le mode d'élaboration, de comparer les oeuvres d'un même sculpteur et de rendre compte de leur état de conservation.
La configuration de l'objet et l'incidence du cliché orientent le choix de l'appareil de rayons X à utiliser et de la technique radiographique à adopter. La pénétration du faisceau varie approximativement de 20 à 120 kV.
Une cinquantaine d'oeuvres ont été étudiées.
Les sculptures sont élaborées avec ou sans l'aide d'armatures métalliques ; dans chaque cas, des procédés distincts apparaissent.
Chaque sculpteur imprime par sa technique un caractère personnel à l'objet qui, dans certains cas, permet l'identification.

BUT DE L'ETUDE

Le Laboratoire de Recherche des Musées de France a entrepris depuis 1981 l'étude radiographique des sculptures en cire afin de déterminer leur mode de fabrication non décelable par l'étude visuelle. Les premiers examens, déjà concluants, de trois objets du XVIIe et du XIXe siècle ont été présentés en poster-session lors de la 6ème réunion triennale du Comité de Conservation à Ottawa en septembre 1981.
Depuis, une cinquantaine d'oeuvres ont été étudiées :
XVIe siècle : J. de Bologne
XVIIIe siècle : E. Bouchardon
XIXe siècle : A.L. Barye, R. Bugatti, A.N. Cain, J.J.M. Carries, H.L. Cordier, E.I.H. Cros, E. Degas, J.A.J. Falguière, E. Fremiet, J.B. Guillaume, P.J. Mène, M.J.A. Mercié, F. Rude, T.A. Steinlein, H.E. Verhnes (+).

Les résultats de ces recherches, assez souvent inattendus, seront une intéressante contribution aux enquêtes sur la sculpture en cire que conduisent actuellement les responsables des collections françaises.

(+) Sculptures appartenant au Département des Sculptures du Musée du Louvre et au Musée d'Orsay.

LES SCULPTURES EN CIRE

Parmi les matériaux malléables utilisés pour façonner les sculptures, la cire, par sa consistance, sa nature et sa fragilité, constitue celui qui offre un rendu des formes attrayant à l'oeil mais particulièrement périssable.
La fluidité du matériau et sa capacité à être travaillé à chaud et à froid permet de modifier les reliefs des sculptures les plus travaillées, celles-ci pouvant être modelées ou moulées selon les cas.

Les rondes-bosses et les reliefs exécutés en cire sont d'une part des oeuvres préparatoires : études, esquisses et maquettes, destinées à être traitées dans un autre matériau : bronze, marbre... mais également des épreuves originales et oeuvres définitives exécutées dans ce matériau au même titre que tel autre constituant plastique utilisé en sculpture.

Les techniques de fabrication sont plus ou moins complexes selon la taille, la forme et le degré d'élaboration de l'objet, esquisse ou oeuvre définitive. La cire peut être employée seule (cire + colorant + charges) ou travaillée autour d'armatures métalliques, de formes en bois..., mais peut également, contre toute apparence, ne constituer que la partie extérieure d'une structure sous-jacente différente.

La radiographie permet de :
- discerner les différentes constitutions,
- retrouver le mode d'élaboration,
- comparer les oeuvres d'un même sculpteur,
- constater l'état de conservation,
- localiser l'emplacement des prélèvements de matière à analyser.

TECHNIQUE RADIOGRAPHIQUE

Les radiographies sont exécutées à l'aide de deux types d'appareils de rayons X :
- l'un autoredressé à fenêtre de beryllium dont la tension d'excitation du tube peut varier de 10 à 140 kV, donnant des clichés contrastés pour les objets peu épais et peu denses,
- l'autre à tension constante (50 à 300 kV) permettant d'obtenir des clichés dont la latitude des densités est plus grande pour les objets denses ou possédant de grandes variations d'épaisseur.

Le choix de l'appareil est déterminé selon la configuration de l'objet, les deux tubes pouvant être utilisés pour étudier la même oeuvre sous des incidences différentes.
La pénétration du faisceau est fonction de la plus grande épaisseur et peut aller de 20 à 70 kV avec des films industriels à grains fins, sans écrans (type Industrex A ou Structurix D4), ou de 60 à 120 kV en utilisant l'appareil à tension constante, des films avec cassettes et écrans renforçateurs au plomb de 0,10 mm. Les clichés obtenus avec une tension élevée permettent de distinguer avec plus de précision :
- la constitution centrale de l'objet,
- la superposition éventuelle de plusieurs couches de cire,
- la présence dans la structure en cire d'autres matériaux : bois, liège...,
- de diminuer l'effet de bords.

La multiplicité des incidences et en particulier celle utilisant un rayonnement tangentiel sert à vérifier la présence et l'épaisseur de la couche de cire superficielle.
Pour obtenir sur un même cliché une bonne visibilité de matériaux superposés ayant une grande différence de densité, tel que plâtre et cire, il est nécessaire de durcir le rayonnement, de réduire le diffusé en plaçant un filtre de cuivre de 1 à 2 mm au niveau de l'objet. Le rayonnement primaire doit également être filtré au niveau du tube par un filtre en aluminium à gradient d'épaisseurs pour les objets présentant de brutales augmentations de volume et de densité.

DIFFERENTES CONSTITUTIONS DES SCULPTURES EN CIRE

Les examens radiographiques, pour la plus grande part, ont été pratiqués sur des rondes-bosses et sur quelques reliefs représentant des études ou des maquettes d'oeuvres sculpturales ou architecturales.

La présence ou l'absence d'armatures métalliques est généralement fonction de la taille et de la forme de l'objet :

- sculptures modelées ou moulées sans armatures métalliques :
  - sculpture modelée, formée par une masse de cire massive plus ou moins homogène,
  - sculpture modelée par la superposition de boulettes ou de colombins,
  - sculpture moulée en creux,
  - sculpture en plâtre recouverte d'une couche de cire,
  - sculpture comportant une âme centrale composée de plusieurs matériaux mais le relief étant en cire ;
- sculptures montées à partir d'armatures métalliques :
  - tiges métalliques rigides, clous, fils métalliques souples ou torsadés permettant des flexions, structures métalliques entrecroisées ou articulées,
  - sculptures constituées de plusieurs parties modelées séparément et assemblées les unes aux autres par de petites pointes métalliques,
  - armatures métalliques complétées par l'inclusion d'autres matériaux servant de support central : bois, liège...,
  - sculptures travaillées autour d'une potence centrale en métal.

A partir de ces différentes constitutions, il est possible de retrouver les stades successifs de l'élaboration, de constater les modifications apportées au cours de la réalisation -changement d'inclinaison d'une tête ou d'un membre-, de reconnaître les sculptures moulées en creux.
Ces particularités techniques, propres à chaque objet, sont également spécifiques d'un même auteur ; la façon de placer une armature ou de tordre un fil métallique est, semble-t-il, très personnel et caractéristique de l'identité d'une sculpture.

TECHNIQUE DE FABRICATION

Parmi les oeuvres examinées, quelques technologies méritent d'être soulignées ; elles évoquent un certain nombre de procédés de fabrication mais ne constituent que des exemples parmi la variété des constitutions rencontrées.

Cire moulée et modelée

Attr. à J. de Bologne - XVIe siècle
"La Géométrie" - Campana 90, Musée du Louvre

Cette sculpture de grande taille (55 cm environ) est constituée de plusieurs parties dont certaines (la tête et le corps) ont été moulées en bivalve alors que les membres pleins ont été modelés sans le secours d'armatures métalliques. L'objet a, semble-t-il, été élaboré à partir de trois grands pitons situés à la base entre lesquels une grande tige verticale est enfoncée et autour de laquelle le corps est maintenu. Les bras et les jambes ont été joints à la sculpture (+).

(+) Exposition GIAMBOLOGNA
Edimbourg 1978 ; Londres 1978 ; Vienne 1979
Arts Council of Great Britain
Ed. Ch. Avery et A. Radcliffe

Cire modelée en colombins

E. Bouchardon - XVIIIe siècle
"Deuxième projet du tombeau du Cardinal Fleury"
R.F. 1778/R. 974, Musée du Louvre

La statuette est en cire pleine et homogène. Elle a été modelée en colombins superposés et distincts pour chaque personnage. L'ensemble a ensuite été unifié et recouvert d'une patine brune masquant la structure interne.

Plâtre et cire

A.L. Barye - XIXe siècle
"Tigre et zibeth" - R.F. 2724, Musée du Louvre

La plus grande partie de la statuette a été faite en plâtre dans lequel on discerne les bulles de fabrication, puis l'ensemble de l'objet a été recouvert d'une mince couche de cire qui forme le modelé de la sculpture. L'inclinaison de la tête a été modifiée avant la mise en place de la couche externe. La queue du tigre, traitée en cire, est maintenue grâce à la présence d'une tige métallique interne.

Potence et armatures

P.J. Mène - XIXe siècle
"Vache et son veau" - R.F. 1903, Musée d'Orsay
"Chèvre broutant" - R.F. 1935, Musée d'Orsay

Les sculptures ont été réalisées à partir d'une potence centrale formée par une grosse tige métallique recourbée et fixée sur le socle autour de laquelle le corps de l'animal a été modelé. Puis les membres, façonnés à l'aide d'armatures métalliques, ont été joints au corps. La position des têtes a été modifiée et l'espace créé par le changement d'inclinaison est comblé avec de la cire. Lorsque les statuettes sont terminées, la potence centrale est alors sectionnée au ras de la paroi ventrale.

Cire + fils métalliques + âme en liège

E. Degas - XIXe siècle
"Cheval arrêté" - R.F. 2772, Musée d'Orsay

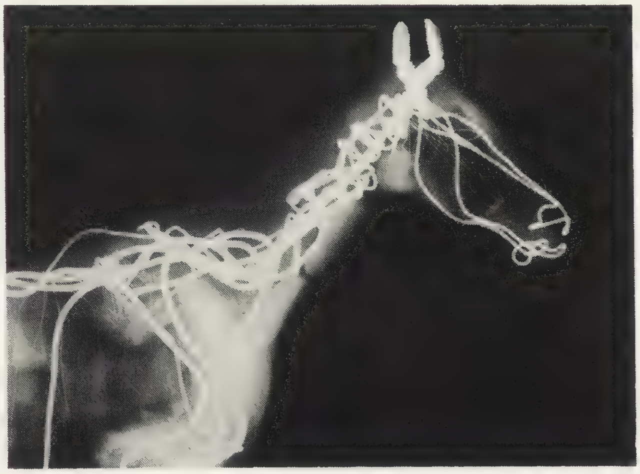

Figure 1 : radiographie
Ossature métallique à partir de laquelle la sculpture a été modelée.
Tête construite à partir d'un bouchon de liège.

Degas a utilisé ici une véritable ossature pour modeler l'animal. A partir d'une tige centrale servant de potence, il a tout d'abord fixé une armature souple qui forme l'arrondi de l'avant-corps creux et va jusqu'à l'antérieur droit ; puis pour former l'arête dorsale, il a placé des tiges métalliques torsadées qui parcourent le dos, des oreilles à la queue ; enfin pour soutenir la tête et les membres, des tiges souples et minces ont été utilisées. Mais Degas a employé d'autres matériaux que cette structure métallique pour façonner l'avant-corps de l'animal et la tête qui a été construite autour d'un bouchon de liège dont la forme est compatible avec cette partie anatomique. De plus, des colombins de cire ont été ajoutés pour accentuer les contours de l'encolure.

Plusieurs parties en cire modelée fixées par des pointes métalliques

H.L. Cordier - XIXe siècle
"Lion accroupi" - R.F. 2253, Musée d'Orsay

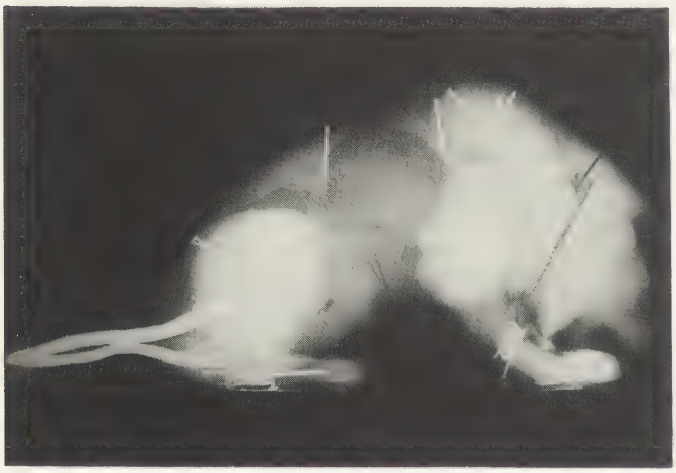

Figure 2 : radiographie
Pointes métalliques fixant les membres sur le corps. La queue est maintenue sur l'arrière-train par une armature métallique.

Figure 3 : schéma d'après la radiographie
1, 2, 3, 4, 5 : parties modelées séparément
A, B : cavités du corps
C : pièce intermédiaire
D : crinière masquant les jonctions de la tête et des épaules

La statuette est composée de sept parties indépendantes modelées séparément. Le corps de l'animal constitue le point de départ de la sculpture ; il comporte deux cavités (A et B) et a vraisemblablement été fait en bivalve. Sur le corps, ont été joints les quatre membres modelés (3 et 4) en plein et fixés avec de petites pointes métalliques. Une pièce intermédiaire (C) placée entre la tête et l'encolure a permis d'orienter la tête dans l'axe désiré. Enfin, le sculpteur a modelé la crinière (D) ; elle recouvre les parties antérieures et masque les jonctions de la tête et des épaules. Seule la queue (5) possède une armature métallique qui la maintient à l'arrière-train.

Tête : plâtre moulé recouvert de cire

J.J.M. Carriès - XIXe siècle
"Tête de Jules Breton"
R.F. 3450, Musée d'Orsay

La tête a tout d'abord été moulée en plâtre, en creux, aux formes exactes du sujet définitif. Ce modèle a ensuite été recouvert d'une couche de cire de 0,5 à 1 cm d'épaisseur qui épouse parfaitement le relief initial. Les cheveux et la barbe ont été repris directement pour parfaire le rendu des détails. Cette technique de mise en forme n'est peut-être pas étrangère au métier de céramiste de l'auteur.

Tête : âme constituée de matériaux complexes + modelé en cire

H.E. Vernhes - XIXe siècle
"Mademoiselle D" - R.F. 961, Musée d'Orsay

Le procédé de fabrication utilisé ici est tout différent de l'exemple précédent. A partir d'une structure complexe utilisant plusieurs matériaux : bois, plâtre, clous..., l'auteur a ébauché la forme d'une tête sans relief évoquant la marotte des modistes. Une couche de cire de 1 à 2 cm a ensuite été appliquée et travaillée pour donner à la sculpture son modelé définitif. Pour discerner la superposition de ces matériaux ayant de grandes variations, il a été nécessaire d'effectuer les radiographies avec des paramètres différents.

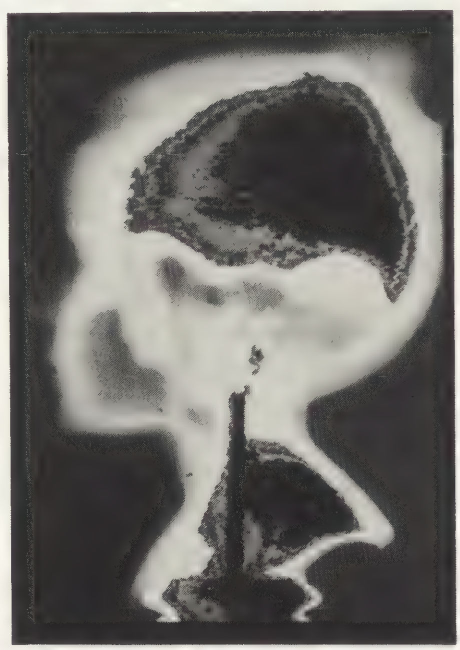

Figure 4 : Traitement de l'image radiographique
Couche externe en cire et délimitation des volumes internes en isocontours.

Le traitement des images après numérisation des clichés, a permis de discerner les couches et la délimitation des volumes par la recherche des isocontours en pseudo-couleurs.

Cire modelée sur "pantin articulé"

F. Rude - XIXe siècle
"Mercure attachant sa talonnière"
R.F. 2643, Musée du Louvre

Figure 5 : radiographie
Tige et attaches métalliques articulées autour desquelles a été façonnée la figurine.

La position contournée de la divinité a été réalisée en modifiant au fur et à mesure le mouvement du corps. Rude s'est servi pour cela d'une tige métallique centrale prolongée par un fil torsadé formant l'axe du corps, la tête et les épaules. A partir de cet axe, sont accrochées des attaches métalliques s'articulant les unes aux autres, placées dans les bras et les jambes et permettant ainsi de modifier la position des membres. Autour du métal, une première couche de cire a tout d'abord fixé l'orientation voulue, puis une couche plus épaisse recouvrant la première a formé la sculpture dans son intégrité.

CONCLUSION

Ces quelques exemples sont à même de montrer la diversité des procédés employés par les sculpteurs malgré la similitude des matériaux utilisés, mais aussi la technique personnelle appliquée par chacun d'eux et imprimant ainsi à l'objet un caractère particulier qui permet dans certains cas à l'identifier.

REMERCIEMENTS

Cette étude a été conduite avec la collaboration de Mademoiselle Anne Tassery à qui nous exprimons notre profonde gratitude.

Nous adressonségalement tous nos remerciements à Monsieur MAITRE, Professeur à l'ENST, responsable du laboratoire IMAGE, qui a permis de compléter l'examen radiographique grâce à l'équipement informatique de l'Ecole.

RECONSTITUTION TRIDIMENSIONNELLE DE "CALCULI" MESOPOTAMIENS

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SOMMAIRE

Un système de comptabilité utilisé en Mésopotamie au IVe millénaire dépend de la forme et du nombre de petits "calculi" en argile inclus dans des "bulles sphériques".
Les radiographies donnent une image globale des éléments inclus, alors que la tomographie densitométrique (scanner) permet leur reconstitution tridimensionnelle. Elle apporte des précisions sur le nombre, la forme et la dimension des calculi, et sur la technique de fabrication de la bulle-enveloppe.
Ces résultats contribuent à l'étude archéologique qui permettra de rattacher ces objets aux systèmes comptables existant dans les grandes agglomérations urbaines de Mésopotamie.

A l'époque d'Uruk, au IVe millénaire, on voit apparaître en Mésopotamie les premiers témoignages d'opérations comptables entre deux partenaires. Ils prennent la forme de "bulles-enveloppes" sphériques en argile de 5 à 10 cm de diamètre renfermant de petits objets de même matière aux formes géométriques variées. Ces calculi (1), de plusieurs ordres de grandeur, correspondraient aux denrées enregistrées. L'extérieur des bulles est couvert d'empreintes de sceaux-cylindres officialisant l'opération. Jointes à l'envoi des marchandises, elles étaient ouvertes par le destinataire qui vérifiait, par leur contenu, la quantité de denrées réceptionnées.

Certaines bulles moins anciennes peuvent comporter, à la surface, des encoches matérialisées sous forme de signes, sortes de notation graphique numérale des calculi internes. La relation entre contenu et signes est encore mal définie : des calculi différents peuvent correspondre à des encoches semblables. Ils représenteraient :

- soit des chiffres abstraits, leurs multiples ou sous-multiples pouvant relever de deux systèmes numériques connus, l'un sexagésimal, l'autre décimal ;
- soit un symbolisme plus spécifique des matières comptabilisées : mesure de capacité, quantité de denrées, effectif de bétail...

La connaissance fine du contenu des bulles-enveloppes permettra seule de déchiffrer cette "forme d'écriture" archaïque.

Quelques objets ouverts ont déjà permis de dénombrer certaines formes de calculi : sphères, disques, bâtonnets, cônes, tétraèdres...
Le contenu d'une quinzaine d'autres, conservés au département des Antiquités Orientales du musée du Louvre, constitue le sujet de cette étude.

Deux techniques d'examen complémentaires ont été utilisées : la radiographie et la tomographie densitométrique (scanner).

Radiographie

Chaque bulle-enveloppe, après inclusion dans un cube de mousse transparente aux rayons X, destiné à stabiliser l'objet et éviter toute erreur de manipulation, a été radiographiée selon quatre incidences, par rotation successive de 90°.

La technique se révèle suffisante pour déterminer un petit nombre de calculi de formes simples. Le déplacement des calculi à l'intérieur de la cavité pseudo-sphérique se traduit toutefois, lors du changement d'incidence, par des images confuses difficiles à interpréter.

Les images d'une bulle-enveloppe du musée du Louvre (fig. 1), choisie à titre d'exemple, ont montré la présence de plusieurs formes parmi lesquelles des projections triangulaires pouvant appartenir soit à des cônes, soit à des tétraèdres (fig. 2). Afin de préciser le nombre d'éléments inclus, leur forme et d'en délimiter le contour avec exactitude, des tomographies ont dû être pratiquées.

Figure 1 : Bulle-enveloppe contenant des calculi
Département des Antiquités Orientales
Musée du Louvre

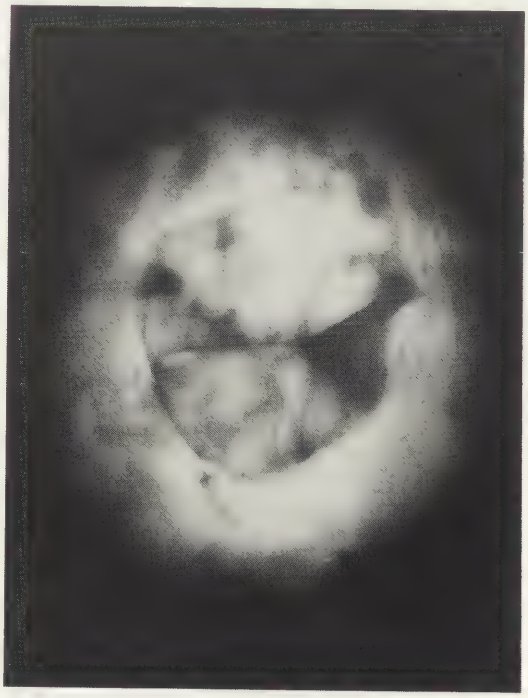


Figure 2 : Radiographie de la bulle-enveloppe montrant des calculi de forme et de taille variées : cônes ? tétraèdres ?

La tomographie densitométrique en usage dans les services hospitaliers a déjà démontré son utilité en archéologie (2) ; elle trouve ici un domaine d'application particulièrement adapté.

Tomographie densitométrique

Le tomodensitomètre ou scanner X est un appareil qui reconstruit l'image d'une coupe à partir d'une série de mesures d'atténuation réalisées dans un plan, mais avec des orientations différentes par rapport à l'objet.

Si l'on considère une coupe de l'objet que l'on divise en un assemblage de volumes parallélépipèdiques, un faisceau de rayons X collimatés balayant la coupe ("scanning") produit un "profil d'atténuation". Ce profil correspond simplement aux variations le long de l'axe de balayage de la somme des absorptions élémentaires de chaque colonne de volumes. Si on fait tourner l'ensemble émetteur X-détecteur autour de la coupe, un nouveau "profil d'atténuation" est obtenu. A partir d'un grand nombre de ces profils, on peut calculer la valeur pixel (picture cell) et la visualiser sur une matrice.

Le résultat est une image dont les valeurs de gris ont la même signification que celle de la radiographie habituelle, mais dont la définition est très supérieure à celle des tomographies classiques.

Les premiers tomodensitomètres employaient les deux mouvements : balayage-rotation, mais on est parvenu à réaliser des appareils rapides ne comportant plus qu'une rotation continue, un ordinateur réalise alors très rapidement les calculs (fig. 3).

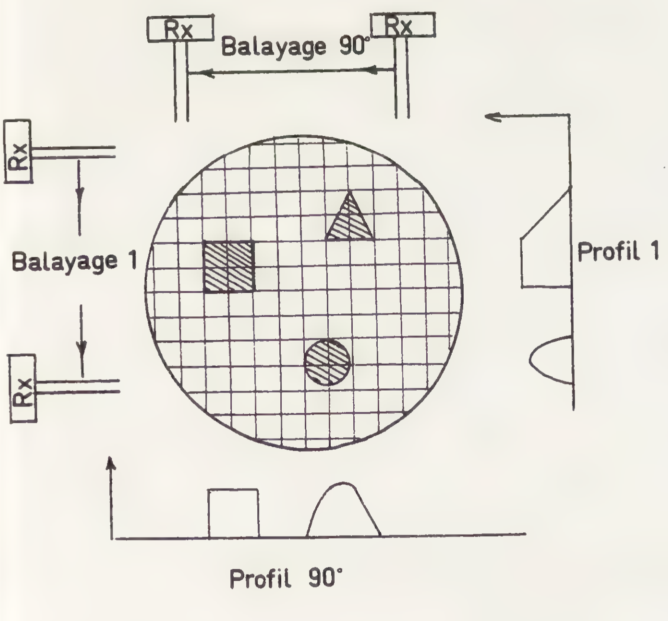


Figure 3 : Principe de l'analyse tomodensitométrique (appareil à translation-rotation)
Dans un premier temps (balayage 1) le faisceau de rayons X collimaté analyse les structures de l'objet ligne par ligne. L'atténuation du faisceau est la somme des atténuations de tous les volumes élémentaires situés sur le trajet du pinceau de rayons. Elle est enregistrée sur les détecteurs sous forme d'un "profil d'atténuation" (profil 1). L'ensemble rayons X-détecteurs est alors tourné d'un ou plusieurs degrés, et une nouvelle mesure est réalisée, puis une nouvelle angulation, etc... Le balayage 90 et le profil 90 sont représentés sur la figure. Les appareils modernes rapides ont un faisceau de rayons X large, et un mouvement unique de rotation continue.

Le C.G.R. CE 10.000 utilisé est un appareil à rotation continue rapide, dont les caractéristiques principales sont les suivantes :
- temps d'acquisition de l'image : 3,4 et 6,8 s.
- temps de reconstruction : 0 à 40 s. selon la définition
- définition spatiale limite en haut contraste : 0,5 mm
- tension max. de production des rayons X : 130 kV

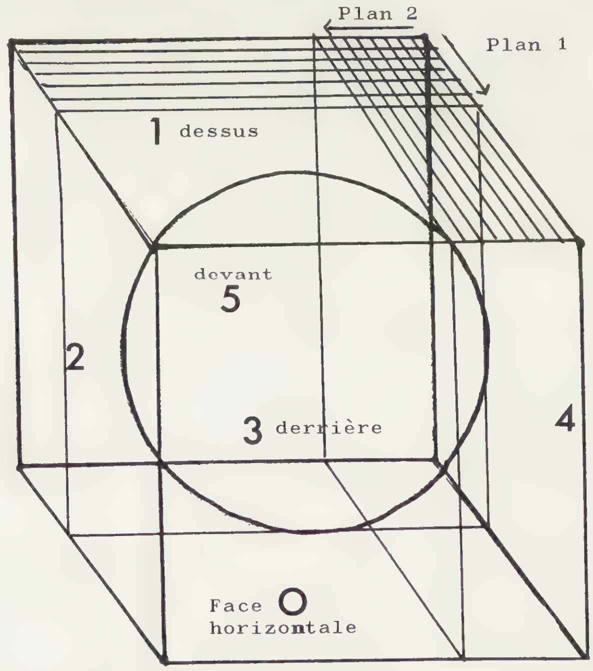
L'image est, dans notre protocole, reconstruite systématiquement sur la matrice-image la plus élevée (512 x 512), la lecture s'effectuant sur 16 bits de gris par un fenêtrage (choix de la gamme de gris que l'on désire représenter). Les valeurs de "densité" peuvent être obtenues directement à partir de la console pour tous les pixels ou groupes de pixels (+).

Le protocole d'examen a été le même pour tous les objets. La bulle, incluse dans le cube de mousse aux faces numérotées, a été placée sur le chariot mobile. Deux plans de coupes parallèles ont été définis (fig.4):

- coupes 1 : face 1 dessus, face 5 devant } coupes du plan 3 au plan 5
- coupes 2 : rotation du cube de 90° dans le plan horizontal
  face 1 dessus, face 2 devant } coupes du plan 4 au plan 2

Les coupes ont été effectuées tous les millimètres dans chacun des deux plans (++).

CALCULI N° L.12049
Plans des coupes au SCANNER



L'étude a été réalisée en deux temps :

- par examen dynamique direct sur console
  . mesures ponctuelles de densité de l'argile de la bulle : paroi externe et centre des calculi
  . mesures comparatives de densité de l'argile des calculi
  . mesure des dimensions des calculi (fig. 5)

(+) Elles sont exprimées en nombres Hounsfield, qui sont une expression du coefficient d'absorption μ des rayons X selon l'équation :
$NH = (\mu x - \mu H_2O)/\mu H_2O \quad 1000$
Dans cette représentation, la valeur de l'eau est 0, les structures denses (os, céramique) atteignent 1000 à 2000, le métal peut dépasser 4000, les cires et graisses donnent des valeurs négatives

(++) Paramètres utilisés : Temps d'acquisition : 6,8 s ; Reconstruction sur matrice : 512 x 512 (mode haute résolution) ; Epaisseur de coupe : 1 mm ; Rayons X : 130 kV, 50 mA.

. comparaison des mesures de calculi de formes géométriques semblables
. détermination de la technique de modelage de la bulle (trou d'évent, bouchon de fermeture)

- à partir des clichés selon les deux axes de tomographie
  . détermination du nombre exact de calculi
  . relevé des formes et reconstitution tridimensionnelle

Figure 5 : Image au scanner de la bulle-enveloppe
Coupe montrant les calculi et mesure de leur dimension

L'examen détaillé de ces objets exceptionnels, de leur technologie, leur contenu et leurs formes, devrait être une contribution notable à l'interprétation archéologique.

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PANORAMIC X-RAYS OF CYLINDRICAL OBJECTS

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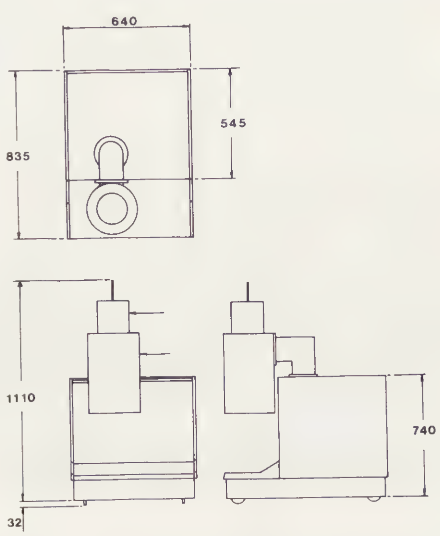
SUMMARY

Advantages and disadvantages of the three techniques for rectangular panoramic radiographs of cylindrical objects are discussed. The first method used a technique from industry where the radiation source is centered within the object. In the latter two methods, the radiation source is placed outside the object, while the object is slowly rotated on a turntable. The radiation is demarcated by a collimator, 2.1 m in length and 2 x 20 mm in the entrance slit and 2 x 120 mm in the exit slit.

X-raying cylindrical objects with conventional equipment currently involves as many as 12 individual radiographs, in order to make a composite panoramic picture. Care must be taken to rotate the object every 30 degrees, so that every part of the surface is equally exposed without obscuring a possible detail or inscription within the curvature of the object. In some cases, a stereo radiograph or a computerized graphic can give the necessary information about an object, but the limiting factor remains the relatively small angle of the X-ray beam in relation to the object's curvature.

The problem becomes even more acute if one has a relatively small object, e.g. 3 mm in height and 15 mm in diameter. There is the possibility of photographically enlarging the image in which the radiograph is treated like a normal negative, but grain size of the film and sharpness of the film-object distance plane become the limiting factors. So what is the alternative?



Electron Gun/Vacuum System of the HDR-X

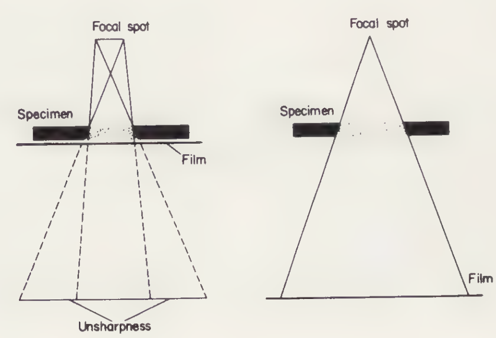
Recently, such a small finger ring came into the Archaeological Conservation Laboratory at The National Museum in Copenhagen, Denmark. It had been found by an amateur archaeologist together with a coin at a graveyard near Tårnby church in Copenhagen. Since there was a whitish corrosion which obscured the inscription, the question arose as to evaluation of the ring and coin in order to arrive at an appropriate finder's fee. For the above mentioned reasons, a regular radiograph proved difficult to interpret. Even with photographic enlargement, only a few letters could be seen. In addition, it was difficult to orient the object. Through Bjarne Jensen at Andrex Co. came the offer to experiment with a new type of high dimension X-ray unit which produced both direct enlargement and a one shot, panoramic radiograph.

The HDR-X unit contains a single micro-focus rod anode system which is surrounded by a clip-on double condensor focusing system equipped with magnetic lenses. The electron gun is of a new design with a 150 liter/sec. turbomolecular pump, allowing the gun to be used in any orientation. The standard rod anode is 13.4 mm in diameter, and 150 mm long, but it can be easily interchanged with a wide variety of rod anodes and directional and radial targets, such as -60° to -5° x 360°, -20° to $+20^{\circ}$ x 360°, -20° to $+20^{\circ}$ x 40°, and $+30^{\circ}$ to $+90^{\circ}$ x 360°. Tungsten is the standard target material, but it can be interchanged with other materials.
The exposure data was as follows,

Film	Exposure Time	kV	μa	Film-Object Distance
Agfa D4	110	50	50	7.5 cm

The initial results provided enough information to begin mechanical cleaning. The direct enlargement capability of the HDR-X increased the 3 mm height of the image seven times, to that of 21 mm. Through mechanical cleaning under the microscope, the mysterious inscription spelled out
M E + M E N + T O + M O + R I + , i.e. "Memento Mori", a latin inscription which translated as: "Remember that you must also die".

Spot tests and high energy dispersive X-rays determined that the metal was brass with an inlay of lead sulfide. The white corrosion on the surface of the finger ring was zinc sulfide. By the casting information obtained by cleaning and the shape of the letters, the curator, F. Lindahl, dated the finger ring to the late 18th, possibly early 19th century. The inscription linked the ring to the Pietism movement in Northern Europe from which has grown the modern day Danish Inner Mission movement.



Direct Enlargement Capacity of the HDR-X

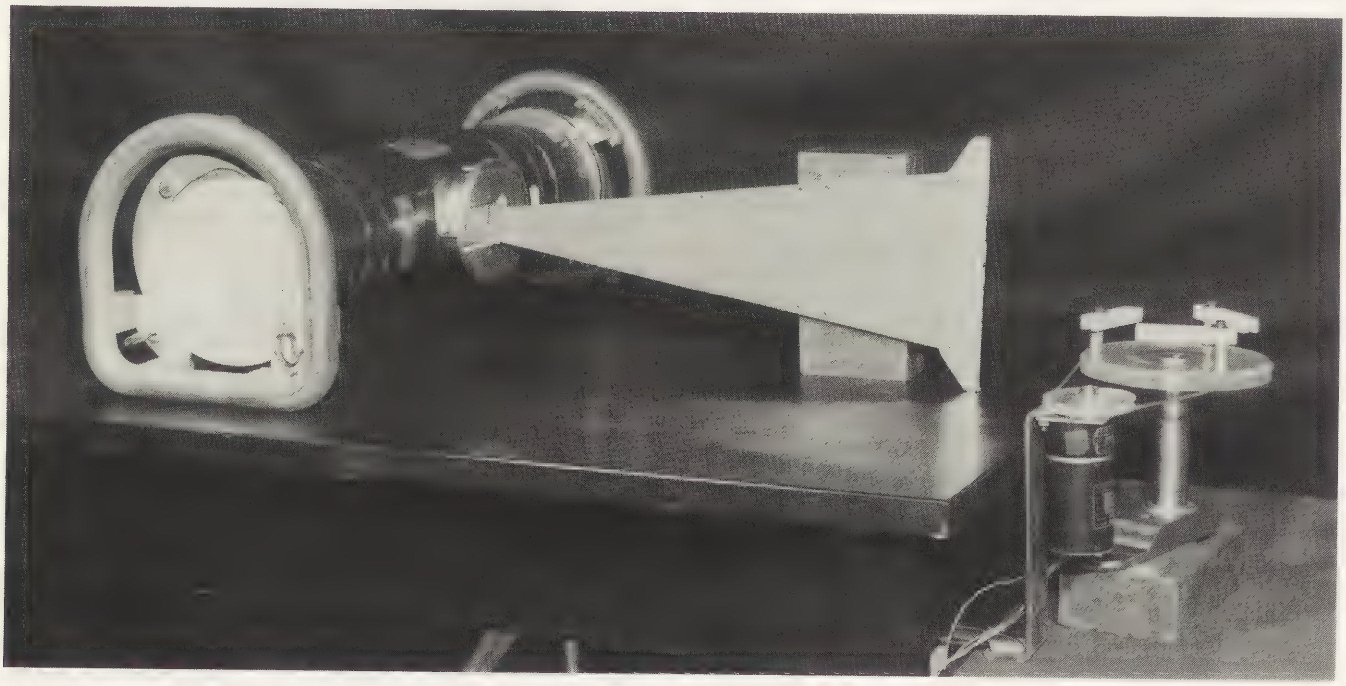
But what happens if your laboratory or museum does not have Andrex and Co. or the HDR-X? One finds an alternative method using a conventional X-ray unit.

The following alternative methods were executed in cooperation with Prof. A. Lindegaard-Andersen, Laboratory of Applied Physics III, Danmarks Tekniske Højskole. In the first instance the X-ray source was a conventional, industrial X-ray unit. The radiation beam was enclosed by a 500 mm collimator with an entrance slit of 2 x 20 mm and an exit slit of 2 x 120 mm. In this experiment, the above mentioned brass finger ring was also used. The ring was centered on a turntable which was driven by a synchronous motor. In this case, the collimator was reduced to 20 mm in the exit slit due to the size of the ring. The film (Kodak MX) was fixed along the inside of the ring. In the centre there was a lead cylinder which stopped the X-ray radiation from penetrating more than one side at a time. During exposure, the ring, lead cylinder, and film were rotated.
Exposure data of the ring were as follows,

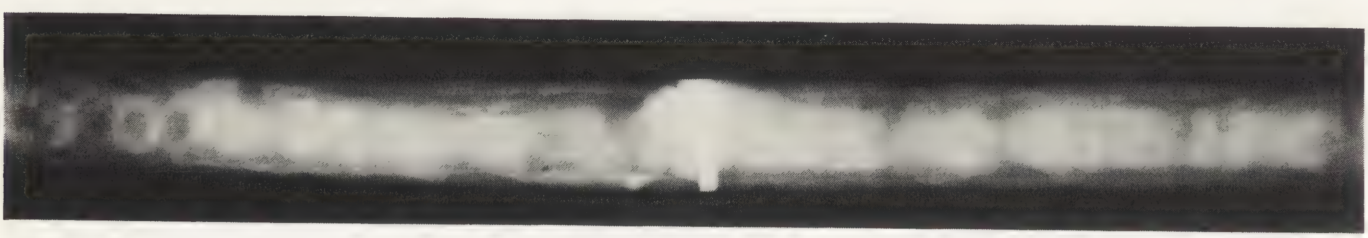
Film	Exposure Time	kV	ma	Revol./Min.
Kodak MX	12 min.	160	4	1

The advantage of this method is ease and simplicity. One uses a conventional, industrial X-ray unit, and a collimator, which is easy to build, and a turntable with a synchronous motor. In this manner, the geometrical unsharpness is very small, in spite of a focus of 1.5 x 1.5 mm, because the focus-object distance is large and the object-film distance is very small. Thereafter, the radiograph can be enlarged photographically. In the above mentioned case, a rectangular picture is obtained which corresponds to an unfolding of the ring and its inscription.

The same technique using a 2.1 m collimator, was also used in the examination of a 5th century B.C. Greek vase which was bought in 1838 by the Danish sculptor Thorvaldsen. Preliminary cleaning by conservator Søren Rasmussen showed that the vase was heavily restored, or possibly a fake. IR and UV photographs were taken before the radiograph. As a reference, a documented vase was photographed beside the vase in question. The surface was examined with X-ray Fluorescence-Energy Dispersive System. The figure on the vase contained a noticeable quantity of lead and iron. A spot analysis 5 cm in front of the face of the winged figure indicated that the amount of iron was greater than the amount of lead. This radiograph was taken with the aid of a Jeol 2 kW



Using a conventional industrial X-ray unit as the X-ray source with a 500 mm collimator.



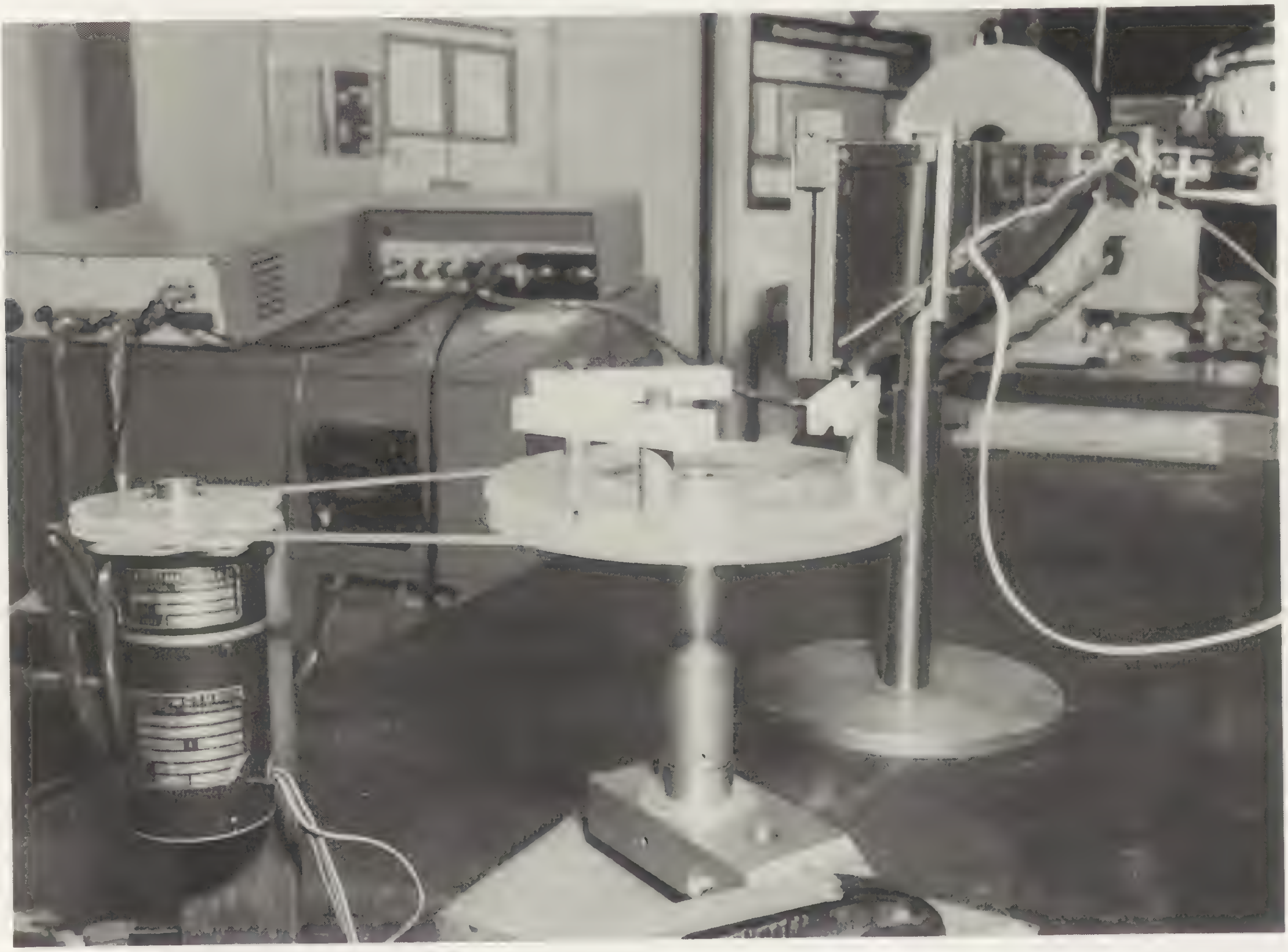
An enlargement of a radiograph showing an unfolding of the ring and its inscription.
This radiograph was taken using the conventional industrial X-ray unit with a 500 mm collimator.

X-ray diffraction generator which has a maximum voltage of 50 kV and the possibility of interchangeable target materials and filters. Otherwise, the technique was the same as above, with the collimator and the synchronous motor.

A molybdenum anode was chosen, because the Mo K radiation (17 and 19 keV) could contribute to a possible increase in the contrast between the composition of the elements in the vase.
Exposure data of the vase were as follows,

Film	Exposure Time	kV	ma	Revol./Min.
Kodak AX	40 min.	45	26	1

With these three methods, a rectangular panoramic radiograph of cylindrical objects can be obtained. This can be a great advantage for the examination of inscription, decoration and technological manufacture of an object, as well as, an aid to evaluate its condition. Each method has advantages and disadvantages. For example, the HDR-X has the following ad-



Using a Jeol 2 kW X-ray diffraction generator with a max. voltage of 50 kV and the possibility of interchangeable target materials and filters, and with a 2100 mm collimator.

This radiograph was taken using the Jeol 2 kW X-ray diffraction generator with a 2100 mm collimator and a molybdenum target. Natural size.

vantages: interchangeable anodes and targets with radial and directional heads and very fine microfocus (0.04 mm). In addition, there is direct enlargement capability, because the X-ray source comes from within the object. The disadvantages are that the anode develops heat and needs to be cooled with a stream of air. With especially small, narrow objects, this could be a problem. In addition, it is difficult to obtain a large focus-object distance, and this can result in reduced geometric sharpness. In certain cases, there is a distortion if the radiation does not intercept the object perpendicularly.

Advantages of the second technique include a relatively inexpensive and easy procurement of the equipment and excellent geometric sharpness due to the long focus-object distance. A possible disadvantage is that the object rotates during exposure, ca. 1 revolution per minute. This risk can be minimized by securing the object firmly onto the turntable. In some cases it is difficult to arrange the film in the object, e.g. if a vase has a small, narrow opening.

Regarding the third variation, the combined possibility of using proper characteristic (monochromatic) X-ray radiation can increase the contrast in the radiograph of elements which would have a small variation of absorption coefficient using normal polychromatic X-ray beams. The disadvantage, of course, is the small photon energy of characteristic radiation and, consequently, the long exposure time.

NOTE

Any queries on the experiments with the HDR-X-equipment should be addressed to Jim Roberts. Any queries on the experiments with the conventional, industrial X-ray unit with a collimator, and the Jeol 2 kW X-ray diffraction generator with a collimator should be addressed to Birthe A. Gottlieb.

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Acknowledgments

The authors would like to thank both Mr. Bjarne Jensen of Andrex Co. and Prof. A. Lindegaard-Andersen, Danmarks Tekniske Højskole, for their cooperation and help.

TREE-RING CHRONOLOGY OF SPRUCE WOOD AND ITS APPLICATION IN THE DATING OF STRINGED INSTRUMENTS

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Summary

Besides the application of comprehensive chronologies for beech- and oakwood used for dating of art objects, more recently it has become possible to establish tree-ring chronologies also for spruce wood, which are now employed especially in the dating of stringed instruments.

The bellies of the stringed instruments mostly manufactured from spruce wood frequently comprise between 100 and 200 annual rings. These tree ring series represent a sufficiently large period of time to allow the relative and absolute dating of the wood. Altogether 50 stringed instruments were investigated and assigned to their time of origin. The recurrence of certain characteristic ring sequences confirms that in most cases the wood used for the treble and bass part of the belly came from the same tree. In addition to the absolute dating some information about wood storage and drying could also be obtained.

Introduction

Scientific examinations of stringed instruments were concerned above all, with the problems of resonance and acoustic (Bucur 1982, Burmester 1965, Cremer 1981, Holz 1967, Hutchins 1978) and, furthermore, with the determination of the wood species used and its origin and properties (Bariska 1978, Dorsch 1975, Ille 1976, Möckel, Winckel 1967, Shigo, Roy 1983). Lottermoser and Meyer (1958) reported on the first experiment in order to achieve a dendrochronological dating of Italian stringed instruments. In this preliminary study a relative correlation of the tree-ring series of three violins could be demonstrated, however, absolute dating was not possible. Up to the present further dendrochronological analyses on violins were only occasionally attempted for individual instruments (Corona 1980, Schweingruber 1983).

Some years ago a comprehensive investigation of the wood of stringed instruments attributed to violin builders at Nürnberg and Mittenwald in the Federal Republic of Germany was initiated and supported by the "Germanisches Nationalmuseum Nürnberg" and "Geigenbauschule Mittenwald".

In a first step chronologies of spruce wood were established with recent trees from sites where the wood for the instruments most likely came from.

The main aim was then to dendrochronologically date the spruce wood of instruments. In addition to the absolute dating of the individual bellies the attribution to a definite geographical origin and a relationship between the felling date of the tree and the creation of the instrument were to be elucidated.

In the following the methodical approach and also some dating experiments should be demonstrated.

Material and Method

In order to establish a chronology for spruce wood statistical measurements of chronological compatibility of recent spruce trees within and between different regions were carried out in particular for the forests around Mittenwald, Nürnberg and Zwiesel in the Federal Republic of West-Germany. The tree-ring series from discs of the recent trees were determined with an Eklund measuring device (Eckstein, Bauch 1969).

In addition 50 stringed instruments from the 16th to the 20th century were investigated at the "Germanisches Nationalmuseum Nürnberg" and "Geigenbauschule Mittenwald".

The tree-ring series of the bellies were taken directly from the objects by means of a calibrated lense (Fig. 1) or by using x-ray photographs, when the varnish on the instrument was not transparent (Fig. 2).

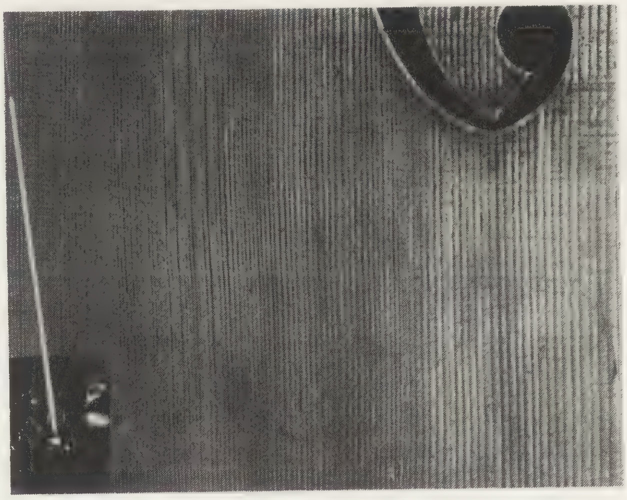

Fig. 1 Section of the treble side of a Violoncello (L. Bisiach, Milano; private property)

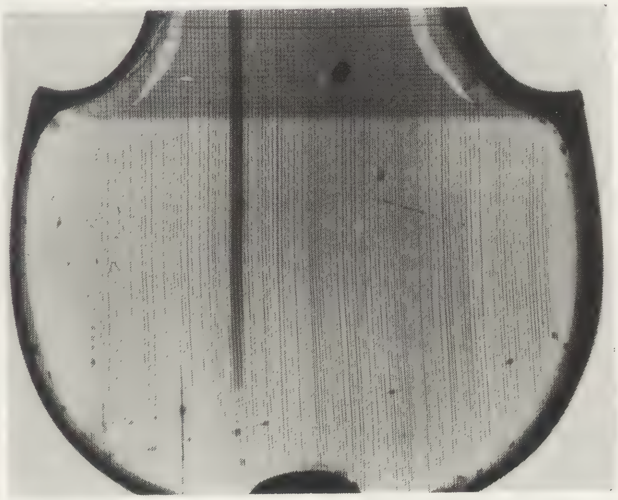

Fig. 2 X-ray photograph of a violino d'amore (MI 16, Germanisches Nationalmuseum Nürnberg)

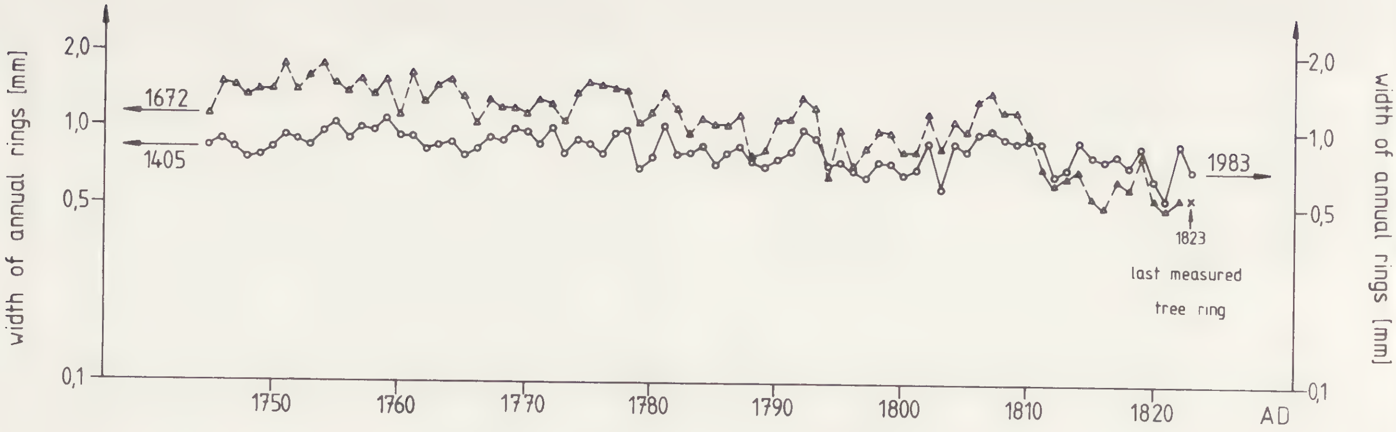

Fig. 3: Comparison of tree-ring curves: o—o - master chart of spruce wood (1983-1406); Δ—Δ tree-ring curve derived from the violoncello of L. Bisiach (Milano); last measured ring attributed to the year 1823.

The tree-ring sequences determined from the instruments were transferred to a semi-logarithmic scale. Subsequently they were synchronized with help of the computer program CATRAS (Computer Aided Tree Ring Analysis System, Aniol 1983).

Establishment and application of spruce chronologies

Based on wood of recent trees and selected instruments, spruce chronologies were established for different regions. Presently these chronologies already cover a continuous span of more than 550 years from the present to the year 1405 AD.

Using these master charts it was possible to determine the last annual ring of the wood used for individual instruments (Fig. 3). More details are given in table 1. It is obvious that as a rule the bellies consist of two parts. Only one instrument (P. Hiltz) contains an one-piece belly, and a bass viola (H. Vogel) was constructed from four thin boards. The difference between the art-historical attribution of the instruments and that according to the last measured tree-ring of the bellies varies considerably. For the violoncello of L. Bisiach maximum difference of 69 years was recorded. However, for most of the instruments differences in the ranges from 10 to 20 years are common.

It is also evident that before joining the bass side and the treble side of the viola da gamba (Jais, A) and the viola (Klotz, I.?) the width of the board used was reduced by different number of tree rings. This can be confirmed by the comparison of the two individual curves representing wood from the same tree, 44 and 57 tree rings were cut off during processing.

The determination of the last tree ring finally leads in some cases to the correction of the historical attribution. For example the alto viola da gamba (Hiltz, P.) could not have been manufactured in the year 1636 because the last measured tree ring was attributed to the year 1643, similarly the viola da gamba (Jais, A.) must have been built after 1742.

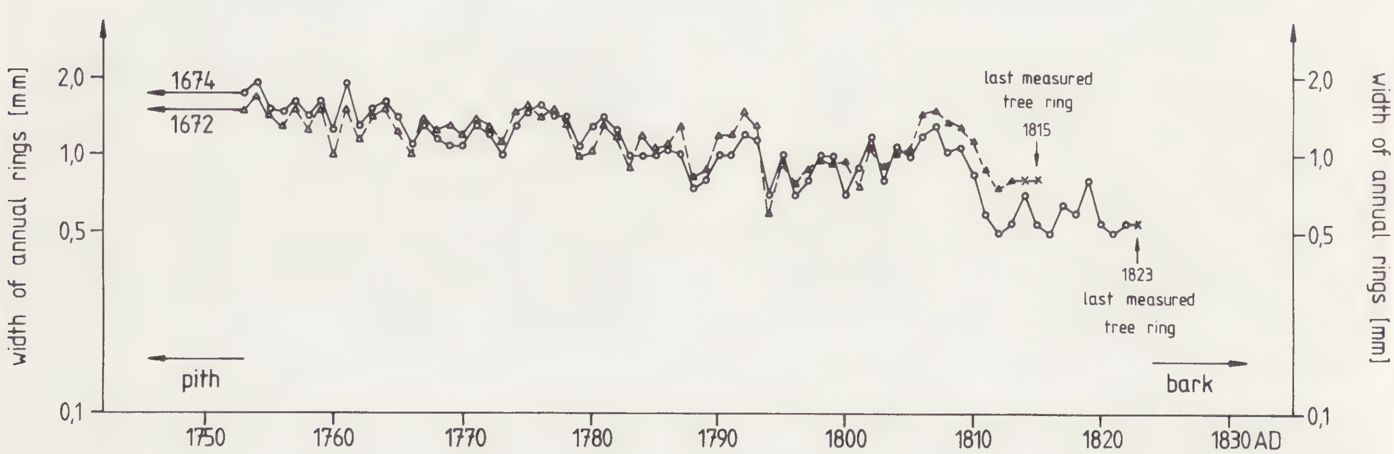

Fig. 4: Comparison of two tree ring curves of the violoncello (L. Bisiach). The two boards came from the same tree. o—o - tree ring curve for the treble side; Δ—Δ - tree ring curve for the bass side.

Instrument maker	Instrument	Historical attribution	Annual rings		Determination of the last measured tree ring		Difference between hist. attribution and last tree ring	
			bass	treble	bass	treble	bass	treble
Bisiach, L. Milano (priv.)	Violoncello	1892	144^{1}	150^{1}	1815	1823	77	69
Widhalm, M.L. Nürnberg (MIR 840)	Violoncello	1780? 1789?	167^{2}	167^{2}	1712	1711	68 77	69 78
Widhalm, L. Nürnberg (MI 26)	Violino piccolo	1769	80	93	1735	1759	34	10
Widhalm, L. Nürnberg (MIR 313)	Large Viola	1757	123	110	1744	1734	13	23
Schelle, S. Nürnberg (MI 365)	Violoncello	1735	152^{2}	150^{2}	1714	1716	21	19
Jais, A. Tölz (MIR 843)	Viola da gamba	1724	242^{3}	286^{3}	1685	1742	39	-18
Hiltz, P. Nürnberg (MI 10)	Alto viola da gamba	1636	158		1643		-7	
Vogel, H. Nürnberg (MI 5)	Large bass viola da gamba	1563	130^{4} 64^{4}	130^{4} 58^{4}	1534 1546	1536 1526	29 17	27 37
– Mittenwald (Vc.a)2)	3/4 Violoncello	~ 1870	183^{5}	192^{5}	1850	1858	~ 20	~ 12
Klotz,(?) I. (?) Mittenwald (Br.a)1)	Viola	1806	148^{8}	205^{8}	1714	1795	92	11
Knitl, J. Mittenwald (-)	Bass	1779	210^{6}	188^{6}	1754	1769	25	10
Leißmiller, M. Krün (Ga)2)	Violin	1750? 1756?	163^{7}	174^{7}	1739	1744	11 17	6 12
"Klotzschule" Mittenwald (Vc.a)4)	Violoncello	~ 1700	269	212	1759	1763	~ -59	~ -63

Table 1: Selection of 13 investigated stringed instruments. The index number (1-8) means the attribution to the same tree.

Besides the sucessful absolute dating of totally 50 instruments, the relative comparison of the spruce boards proved beyond doubt that the bass and the treble sides were in most cases taken from the same tree (Fig. 4). The characteristic tree-ring sequences of the instruments M.L. Widhalm (MIR 840) and S. Schelle (MI 365) show then to be almost identical. In this case the last tree ring could be dated to the year 1716.

Conclusions

From the dendrochronological investigations of stringed instruments it becomes evident that a "terminus post quem" for the creation of an instrument can be determined. An exact dating to the year, however, is not possible, because this method is restricted to the last tree ring available for measurement.

From the absolute dating of many instruments however, it can be concluded that for making the instruments the entire tree radius was often utilized and merely the bark removed. A more detailed information about approximate periods of wood storage and drying can be given only after the final evaluation of the results from all instruments investigated. It is obvious that the storage time of the wood varies considerably and some tree rings were often cut off. The difference between the last measured ring on the tree and the historical attribution of the instruments shows the possibilities and the limitations of dendrochronology. In future the establishment of extended master chronologies for spruce from different geographical regions will allow a more accurate attribution of wood used for bellies to its origin.

Acknowledgements

We are indebted to Mr. F. Hellwig, Germanisches Nationalmuseum Nürnberg and Mr. K. Roy, Geigenbauschule Mittenwald for their active cooperation; to FD Waldherr (Forstamt Zwiesel), FOR Krauss and Mr. Reiser (FA Mittenwald) to supply us with spruce samples for the chronologies.

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NON-DESTRUCTIVE METHOD FOR MEASURING THE REFRACTIVE INDEX OF AN ANCIENT GLASS BEAD

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SUMMARY

Most popular method for measuring a refractive index of an ancient glass bead is the Becke line method. However this method is not always available for all valuable beads, because we must break the bead a little to take a small piece from it.
The method developed here uses a laser. A bead was immersed in oil with a refractive index slightly different from the bead. Then a laser beam was applied to the bead and the angle of deviation due to the difference in refractive indices between the bead and the oil was measured. The same procedure was applied successively by changing the oil. The refractive index of the bead was calculated by plotting these results on co-ordinates of angle of deviation - refractive index of the immersion oils.
This method is completely non-destructive and has a satisfying precision. Many ancient glass and translucent stone beads in Japan are now examined by this method.

1. INTRODUCTION

There are several methods to measure the refractive index of glass. If the glass is homogeneous and if we can cut it into regular shape (triangular or rectangular), it is not difficult to determine the refractive index up to six significant figures. These destructive methods, however, are not appropriate for art objects and only the Becke line method is popularly used to measure the refractive index of an ancient glass; although this method is not entirely non-destructive, it requires only a small piece of glass.

The author has developed a completely non-destructive method for measuring the refractive index of an alkaline glass bead. The refractive index is calculated from the angle of deviation of a laser beam (He-Ne and He-Cd) caused by the differnce in refractive indices of the bead and the immersion oil. Since this method does not require taking a sample from the bead and no trace remains after measurement, many ancient glass beads in Japan are now examined by this method.

2. METHOD OF MEASUREMENT

Figure 1 shows the optical setup. Before measuring, the refractive index of the bead was roughly estimated from its specific gravity; the latter may be determined, for example, by heavy solutions. Then the bead was immersed in oil of which the refractive index

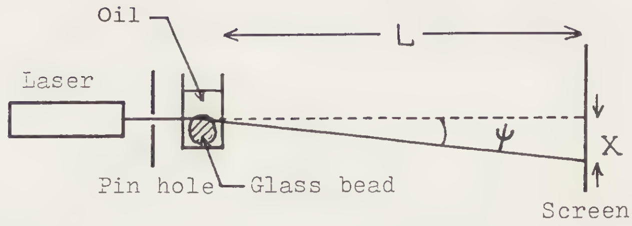

Figure 1. Optical setup for measuring the refractive index of a bead

is slightly different from the bead. A laser beam was applied to the bead and the deviation X due to the difference in refractive indices was measured on a screen. The angle of deviation ψ was given by X/L. The measurements were taken at a constant temperature to avoid fluctuation of the refractive index of the oil.

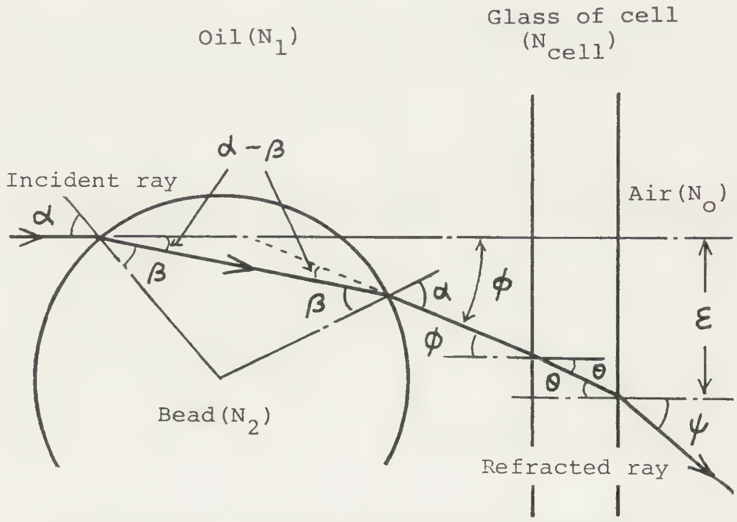

Figure 2. Cross section of the bead showing path of refracted ray

Figure 2 shows a geometric relation between an incident ray and a refracted ray. We have the following expressions:

$$\phi = 2(\alpha - \beta) \quad (1)$$

$$N_1 \sin\alpha = N_2 \sin\beta \quad (2)$$

$$N_1 \sin\phi = N_{cell} \sin\theta = N_o \sin\psi \quad (3)$$

Since both ϕ and ψ are small ($L \gg X$),

$\sin\phi = \phi$

$\sin\psi = \psi$

When the distance L between the cell and the screen is enough large, the deviation of the light path in the cell (ε) is negligible.

$$\psi = \frac{X-\varepsilon}{L} = \frac{X}{L}$$

Then from the expression (3),

$$\phi = \frac{N_o}{N_1}\psi \doteqdot \frac{N_o}{N_1}\frac{X}{L} \quad (4)$$

From the expressions (1) and (2),

$N_1 \sin\alpha = N_2 \sin(\alpha - \phi/2)$

The right side is expanded in Taylor's series and divided by $\sin\alpha\,(\neq 0)$, yielding

$$N_1 = N_2\left\{1 - \frac{\phi}{2}\cot\alpha - \frac{1}{2}\left(\frac{\phi}{2}\right)^2 - \cdots\cdots\right\}$$

Terms above two orders can be ignored when the measurement is carried out under the condition $\alpha \approx \pi/2$ (tangential incident ray) and $\phi \ll 1$ ($L \gg X$). As a result, the following expression is available to calculate the refractive index N_2 of the glass bead:

$$N_1 = N_2 - \frac{N_2 \cot \alpha}{2} \phi \qquad (5)$$

where

$$\phi = \frac{N_o X}{N_1 L}$$

N_o: refractive index of air (=1.000)

N_1: refractive index of oil

N_2: refractive index of bead

α : angle of incidence of laser beam (constant)

L : distance between cell and screen (constant)

X : deviation on screen

Pairs of data (N,X) i.e. (N,ϕ) were measured by changing the oil. The data were represented in a co-ordinate system, O-ϕN, thus yielding the refractive index N_2 of the bead as a cut of O-N axis (see figure 3).

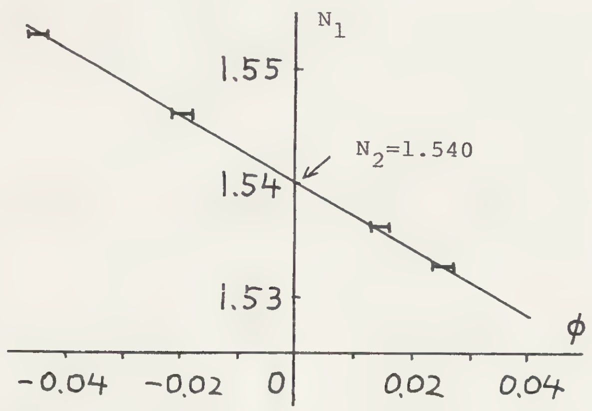

Figure 3. An example of the plotting of a result

3. CALCULATION OF THE STANDARD REFRACTIVE INDEX

Since the refractive index of a glass bead changes according to the wavelength of the incident ray, the standard refractive index is defined according to a standard wavelength (λ_d =587.6nm). The standard refractive index was calculated from a pair of refractive indices measured by He-Ne laser (λ_{He-Ne}=632.8nm) and He-Cd laser (λ_{He-Cd}=441.6nm).

An approximate expression given by optical glasses (from data against 3 wavelength: λ_g= 435.8nm, λ_d, λ_c=656.3nm) is

$$N_d = 0.2N_{He-Cd} + 0.8N_{He-Ne}$$

Although the relation between a refractive index and a wavelength is not linear, this approximate expression produced satisfying results.

4. EVALUATION OF THE MEASUREMENT PRECISION

Optical glass beads of precisely known refractive indices were examined to evaluate the precision of the measurements. Table 1 shows the results.

The precision was ±0.001. Since an ancient glass is not uniform and the difference of the refractive indices within one bead is supposed to be more than ±0.001, a refractive index of four significant figures is sufficiently precise.

Glass	N_d(true)	N_d(measured)
C10	1.50137	1.502
BSC7	1.51680	1.518
ELF6	1.53172	1.532

Table 1. Measured compared with true refractive indices

5. CONCLUSION

A non-destructive method of measurement of the refractive indices was developed for ancient alkaline beads. The precision of the measurement was ±0.001. This is sufficiently precise for ancient glass beads which are not uniform like optical glass.

This method is also applicable to a translucent stone bead. The author is presently conducting measurement of many ancient glass and translucent stone beads in Japan by this method.

ACKNOWLEDGEMENT

The author would like to express his thanks to Mr.Motomura, Tokyo National Museum, Mr.Kariya, Nippon Kogaku K.K.,and Mr.Niiyama, Tokyo National University of Fine Arts and Music.

DESIGN OF THE PORTABLE APPARATUS OF AN INFRARED TELEVISION CAMERA

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SUMMARY

A portable apparatus was designed for examination on high position paintings, which consists of a remotely controlled infrared television camera on a lift. The lift divided into small parts for transportation extends four meters. Using this apparatus we can investigate many paintings within a short time by a few researchers. The author shows an example: researches into column paintings (about five meters high) at a mediaeval temple in Kyoto. The apparatus revealed the paintings of Buddhas entirely darkened and invisible with the naked eye. The result is significant for the Japanese art history.

1. INTRODUCTION

We, staffs of Tokyo National Research Institute of Cultural Properties, began the researches by an infrared television camera in 1974. During these 10 years the infrared television camera became one of the most useful methods for the researches into archaeology and art history in Japan. Museums and universities purchase infrared television cameras as useful equipment for the study of underdrawings and/or excavated materials (documents written on wooden strips or wastepapers soaked by Japanese lacquer). The infrared television camera spreads widely is most probably because it displays an infrared image then and there, while an infrared film requires time for development after photogaphing.

The infrared television camera has another merit which is not commonly known. The infrared television camera makes it possible to observe high position paintings with no danger: the camera can be operated at a safe place, while the remote-controlled camera head is on a high staging. The apparatus was designed for the researches into column paintings of a mediaeval temple in Kyoto.

2. DESIGN OF APPARATUS

The apparatus consists of two infrared lamps, a camera head, a control unit, a control box for a zoom lens, two monitor televisions, a video recorder and a lift.

2.1 Camera head

The camera head is equipped with a zoom lens. Its focus, iris and zoom (framing) are remotely controlled by a control box put on a control unit of the camera. The focal length changes from 18mm (very wide angle) to 108mm (telescope). The smallest frame of view is about 9 X 6 (cm) with the focal length of 108mm at the closest distance (1m) to a painting.

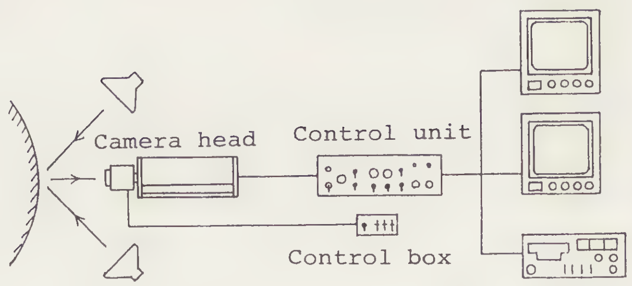

Figure 1. Diagram of the apparatus

In this case a drawing is enlarged on a screen of a monitor television (about three times enlargement on a 12inches screen), which provides a detailed observation of drawings.

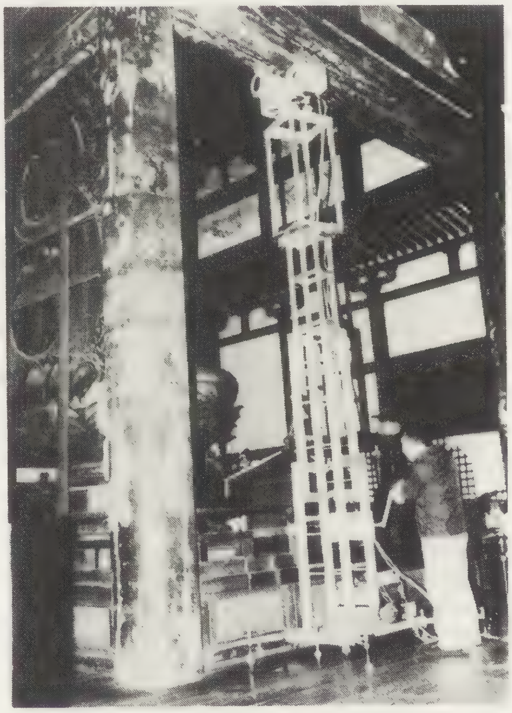

Figure 2. Lift

2.2 Lift

Since portability is one of the merits of the apparatus, the lift was designed to be divided into three parts. Each part can be carried by within a few peoples.

The lift has two extension steps drawn out by a hand-winch (see figure 2) and can be stopped at any height from 1.2m (stowed) to 3m (extended) and further to 4m with an added extension step. One or two persons can easily move the lift due to castors. For observation the lift is settled securely by supporting arms and rods.

2.3 Monitor television

The resolution of the infrared vidicon tube used for this apparatus (Hamamatsu, N214-06) is 700 lines. A monitor television for general use (700 lines in center) has an insufficient resolution near the edge of a screen (see figure 3).

One of the methods for a detailed examination is to enhance drawing lines by image processing (see figure 4). In this case the result,

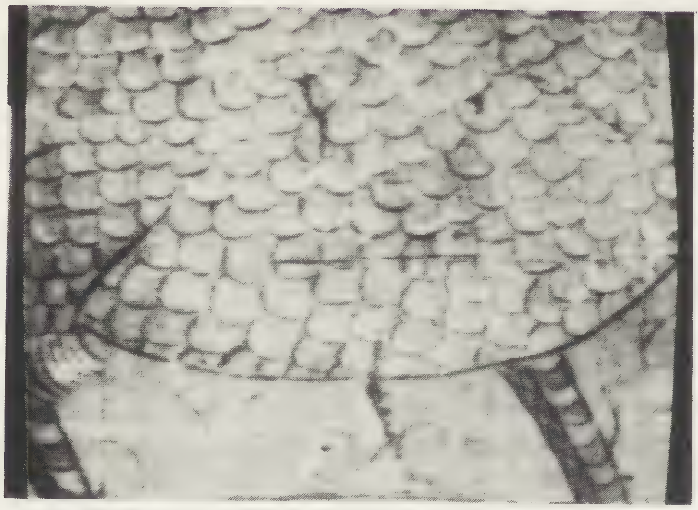

Figure 3. Normal infrared television image

Figure 4. Enhanced infrared television image

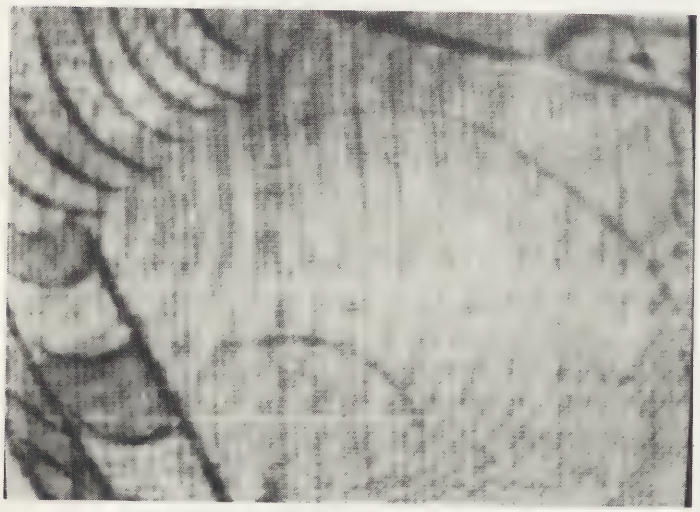

Figure 5. Infrared image of the high-resolution monitor television

however, was not satisfying, because the quality of the image became worse than the original.

The high-resolution monitor television (more than 1000 lines in center) provides a detailed examination without image processing, keeping the good quality of the image (figure 5).

2.4 Video recorder

The infrared images of paintings are recorded in a video tape with in situ comments. We can discuss the paintings afterwards. This is very helpful when we must investigate many paintings in a limited time.

3. APPLICATION

Column paintings at a mediaeval temple (13 century) in Kyoto was investigated by the apparatus. The temple has four ornamented columns at corners of a platform of Buddha. Some of the paintings were photographed by an infrared film in 1957 by Tokyo National Research Institute of Cultural Properties. Since it was difficult to construct a scaffoldin for all columns in a limited space and time, most of the paintings remained unexamined.

Our researches were carried out four times from 1980 to 1983. The apparatus revealed the details of the paintings which was not visible by an infrared film. Through the researches almost all the names of Buddhas were determined from their styles or from their belongings. Their arrangement ("mandala") was resolved then, which is essential to define the Buddhism school of the temple when the columns were painted.

The columns were possibly painted together with walls having visible paintings of flying nymphs, because the two have similar drawings. This result is significant for the study of Japanese art history.

Thus we accomplished fruitful researches due to the apparatus in spite of a few researchers and a limited time and expense.

ACKNOWLEDGEMENT

The author would like to express his thanks to his colleagues: Dr.Akiyama, Gakushuin University, Miss Yanagisawa, Mr.Sekiguchi and Mr.Nokubo, Tokyo National Research Institute of Cultural Properties and Mr.Donohashi, Kobe University.

THE EXAMINATION OF WORKS OF ART BY MEANS OF X-RAY COMPUTER-TOMOGRAPHY (CAT)

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Summary

CAT is a new nondestructive technique of analysis extending considerably the possibilities of conventional radiography. CAT provides sections through the object, while radiographs are shadowgraphs where all details are projected in one plane.

Peculiarly remarkable is the high resolution of densities by CAT reaching values of 0.1 % in medical application. CAT provides unique possibilities of examination in those cases where details in the interior of strongly absorbing coverings are to be made visible.

Techniques of nondestructive testing are of peculiar importance for the examination of works of art. The application of X-rays for the solution of historical problems, proposed by Röntgen himself in 1896, one year after their invention, are one of the main analytical techniques in archaeometry and the techniques of radiography soon were applied by the laboratories of museums.

It is the aim of radiography to obtain informations on the internal structure of historical objects, on their material, the manufacturing techniques or on existing damages without injuring the object.

One of the main applications of radiography is the idenfication of the contents of closed structures. The department of precolumbian art of the museum of ethnology in Berlin has a big collection of peruvian mummies, which are wrapped in cloth together with various additions of objects for everyday use, jewels and food. The whole was sewed in a linnen bag and buried. The archaeological evidence would be completely destroyed, if the bags would be opend and the mummies freed from their bandages. Conventional radiography can provid essential informations on the contens in this case. Difficulties arise if objects which do not attenuate the X-rays are enclosed in heavily attenuating materials like metals or ceramics. Ethnologists working on indian art for instance are interested to know, if there are rolls of paper with texts of historical interest in the interior of bronze statues, closed on the bottom with a copper plate. Similar problems arise, when the casting techniques has to be investigated. The position of the corholders, the type of the filling of the interior, the technique of connection of individual parts do not provide a clear image if X-raying is used, because of the scattering of the radiation or superposition of images from more complicated objects.

Finally, radiography of art objects is necessary to find out the most effective way of conservation. Corrosion phenomena on the surface or the efflorescence of salts frequently are due to reactions in the interior of an object so that a survey of the condition of materials in the interior is a guarantee for the right choice of the way of restoration.

To get as detailed informations as possible for the solution of these problems it was reasonable to carry out a series experiments with the aim to check, if it is possible by means of computer-tomography to obtain results which supply us with supplementary data on the properties of materials.

The application of CAT for nonmedical examinations gains permanently in interest since 1978/3,4/. But there are only a few applications in archaeometry /1,2/ until now.

The principle of CAT

The attenuation of monoenergetic X-rays in materials follows an exponential law.

$$I = I_o \cdot \exp\left[-\int \mu ds \right] \qquad (1)$$

I_o = incident intensity of the radiation
I = attenuated intensity of the radiation
μ = linear attenuation coefficient of the specific material
ds = incremental line element in the direction of the beam

When conventional radiography is used, the two - dimensional distribution of intensity on the X-ray film does not permit unequivocal conclusions on μ, for only the product μ ds in known. This disadvantage does not arise with CAT. With this technique it is possible to determine the linear attenuation coefficient as a function of space coordinates $\mu = \mu(x,y,z)$. By reason of measuring techniques the three-dimensional distribution $\mu(x,y,z)$ normally is obtained as a series of two-dimensional sections $\mu(x,y)$.

The possible principles of CAT are already described in a series of review articles /5-10/. Compared with the fan-beam-machines (fig. 1a) which are almost exclusively applied in medicine the linear-scanner (fig. 1b) is more advantageous for material-testing because of a better flexibility, particularly with respect to the various dimensions of the objects.

The principle of a linear scanner with one beam and one detector is shown in fig. 2. At each angular position the system source-detector is moved step by step gathering that way all data from the whole cross section through the object. The already mentioned collimation of the beam has a decisive importance, for only by reducing the scattered radiation as far as possible the revealing of very fine details becomes possible.

By scanning the object for each angle an absorption profile is obtained, which is composed by single data points (eq. 1). By inverting equation 1 one obtains the line integral p of the attenuation coefficient $\mu(x,y)$ in the direction of the beam along a way through the object

$$p = \ln \left[I_o/I \right] = \int_s \mu(x,y) \cdot ds \qquad (2)$$

which is called projection in the following. The sum of all projections is the basis for the various image reconstruction techniques which can be grouped into three classes:

1. Iterative-algebraic reconstructions
2. Fourier-techniques
3. Techniques with a filtered backprojection.

These techniques are described in a series of articles /11-15/. Therefore it is sufficient to describe in the following only the filtered backprojection technique which is the most common one in practice. The advantage of this technique is first the rapidity of the algorithm reconstruction, secondly by the possibility to treat each profile immediately in the computer parallel to theregistration of further projections.

Fig. 3. shows in detail the geometry of a linear scanner. According to the collection of the data the projection p is described as function of the angle φ and the distance r from the center of rotation:

$$p_{(r,\varphi)} = \ln \left[I_o/I \right] = \int_s \mu(x,y) ds \qquad (3)$$

For each projection these data are folded with a filter function

$$p_{(r,\varphi)} * h_{(r)} = f_{(r,\varphi)} = \int P_{(r',\varphi)} \cdot h_{(r-r')} \cdot dr \qquad (4)$$

and back-projected into the matrix of the image-plane:

$$\mu_{(x,y)} = \frac{1}{\pi} \int_0^{\pi} f(x \cdot \cos\varphi + y \cdot \sin\varphi) \, d\varphi \qquad (5)$$

The argument $x \cos\varphi + y \sin\varphi$ selects all those projections which contribute to the value of μ in the point (x,y). The necessity of filtering the single projections can be explained in the following way:

Each point of the image can be described as a superposition of straight lines, with a bell shaped curve as result the flanks of which slope with 1/r. The backprojection without folding would represent a distribution of the attenuation

coefficient folded with 1/r.

$$\mu_{(x,y)} * 1/r$$

A further advantage of the image reconstruction by filtered back-projection is that the defolding is possible for each single projection and not only on the complete image. The development of the image from the measured data according to this technique is shown in fig. 4.

Examples of application:

The first example to demonstrate the possibilities of this non-destructive testing method is the head of a peruvian mummy from the Museum of ethnology at Berlin. X-ray radiography revealed a plate or foil, impermeable for soft X-rays, in the region of the forehead. It had to be found out whether this head had a perforation of the forehead, which was closed or covered by the metal plate. By means of CAT a section through the head was obtained, showing that the bone is not injured. Over the metal foil a layer of cloth is clearly visible.

In another case, a statue of the god Mercury from the 19th century, the technique of connecting arms and legs with the body should be revealed. On the surface of the sculpture around the upper parts of arms and legs fine traces of a joint were visible. In the region of these joints two cross sections taken by CAT clearly show that in the hollow thigh metal rods are inserted, connected with the inner side of the casting. The supporting tubes are open on one side with the sharp edges bent to the interior. Whether the single parts of legs and arms are connected by soldering cannot yet be deduced from the tomograms because of the still relatively weak resolution.

In a third example also the technique of connection of different parts of metal has to be investigated. The object was a statue made of solid iron, representing a knight fighting a dragon from the 17th century. The artist had claimed that the whole statue was carved from one big piece of iron. A tomographic section in the hight of the horse tail revealed apart from some small voids in the body of the horse a zone of lower density of the material in the region where the tail is connected with the body, proving that it was ficed later. The later connection of two parts of this sculpture was also clearly visible where the tail of the dragon was fixed to the body.

The fourth example is a hollow cast metal statue of a horseman from the 20th century. CAT makes clearly visible some core holders in the interior of horse and horseman. Further it can be seen that horse and horseman are still completely filled with a homogeneous core material, while another man, guiding the horse is hollow. From the histogram of the tomogram it is even possible to calculate the attenuation coefficient μ of the core material. By comparison of the known attenuation coefficient of bronze a value of μ = 0.1 cm -1 is obtained, corresponding to the attenuation coefficient of SiO_2 for Co-60-radiation. A further observation made by CAT are light spots conically broadening from the interior to the surface. These are zones of a higher density than that of the core material which are probably due to corrosion along the iron core holders.

From an egyptian statue of Osiris from the 5th century BC the technique of manufacture and the inner structure could be studied. CAT shows that the object is hollow and the mental is relatively thin. Even the bowlshaped end of the crown is hollow. The interior is homogeneously filled with a core material. Cavities in the region of the arms and the lower part of the statue were made recently when samples were taken from the core. In the region of the head an inclined metalplate in the region of the throat and a pin in the crown can be seen. In the legs too and in the upper parts of the arms metallic inclusions are visible, connected with the inner side of the statue.

The last example shows obviously the high density resolution of CAT. Tibetian metal statues of Buddha some times hide rolled sheets of paper which are not accessible, for the bottom is closed by a metal plate. This plate normally will not be removed just to look if something is inside the statue or not. By means of CAT is was possible to localize in the interior of a bronze object with walls of 3 mm such a roll of paper, without injuring the statue.

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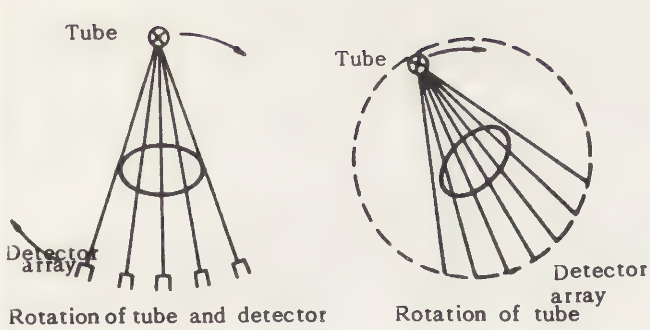

Fig. 1a Fan beam CT scanner

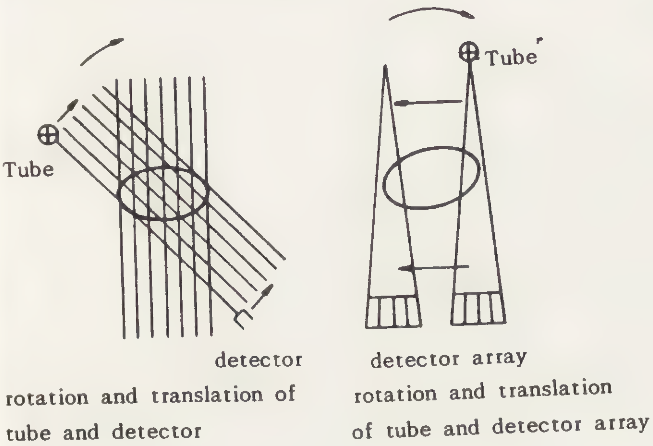

Fig. 1b Priniple of a linear scanner

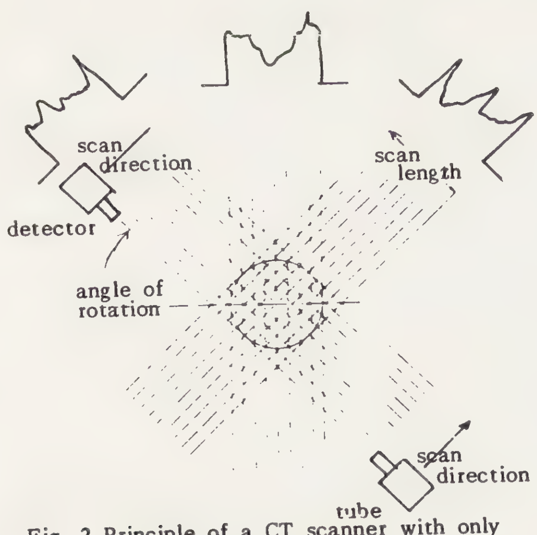

Fig. 2 Principle of a CT scanner with only one beam and one detector
(after Herrmann,F. a. Ungerer,K.: Die Computer - Tomographie. Elektronik 1978, 4, 54 - 61)

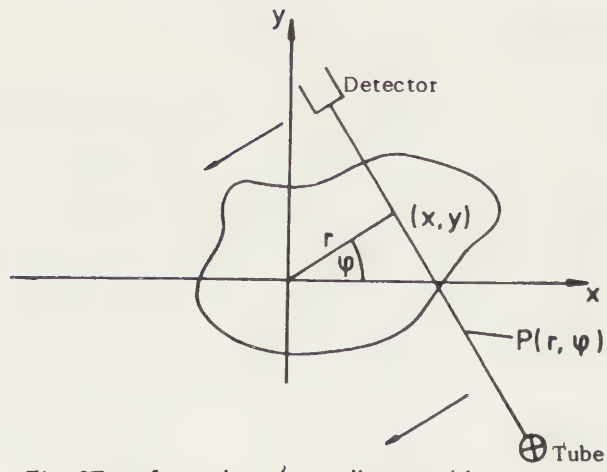

Fig. 3 Transformation of coordinates with a linear scanner

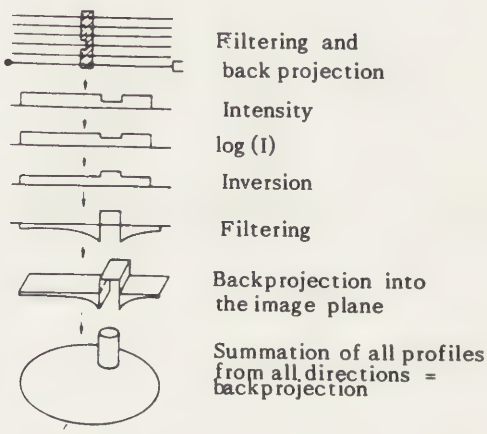

Fig. 4 Effect of filtering and back projection

SECONDARY ION MASS SPECTROMETRY FOR THE MATERIAL CHARACTERIZATION OF ART OBJECTS

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SUMMARY

Secondary ion mass spectrometry (SIMS) is based on the bombardment of solids by ions and subsequent mass spectrometric analysis of the ions sputtered from the target. It provides comprehensive elemental and isotopic analysis with extremely high sensitivity, "in situ" characterization of thin films and three dimensional distribution of elements at the surface of solid samples. The principle of the technique, some important parameters for analysis and possible applications for the characterization of art objects and ancient materials are discussed and results obtained by SIMS-investigations on naturally weathered medieval window glass of Austria are presented.

INTRODUCTION

For the study of the material composition of art objects and ancient materials an elaborate analytical characterization has to be performed. Information has to be obtained about bulk composition, morphology and species of single particles or phases and the surface of substances. The most important techniques used for the elemental analysis are the x-ray fluorescence analysis (XRF), optical emission spectroscopy (OES) and atomic absorption spectroscopy (AAS) or even neutron activation analysis (NAA) and particle induced x-ray emission spectroscopy (PIXE) (1, 2). For the characterization of surfaces and microdomains - complete quantitative multielement analysis and distribution of the elements - electron probe micro analysis (EPMA) has been proved to be very useful (2, 3).

Although EPMA is a powerful tool for rapid, accurate nondestructive analysis of micrometer size areas in a wide variety of specimens this analytical technique has certain limitations which restrict its application to works of art in some cases. The problems are caused by rather low depth resolution of analysis due to the significant penetration of the electron beam into the sample. The information depth of the characteristic x-ray generated in the target is typically in the order of a few micrometers. The technique of the electron probe microanalyzer is also limited by its analytical sensitivity especially for light elements such as O or F and its inability to detect hydrogen. Consequently little is known of the behavior of the light elements especially H or O during corrosion processes of metals, ceramics or glass.

Secondary ion mass spectrometry (SIMS) is the technique capable of "in situ" microanalysis of microdomains and surfaces at elemental abundance levels in the ng/g to µg/g range with adequate sensitivity to cover the analysis of light elements including hydrogen.

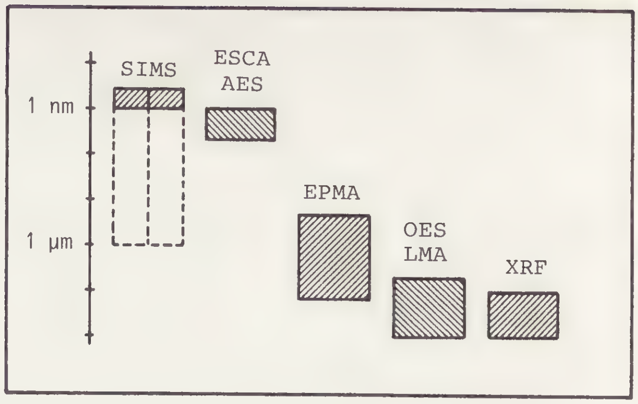

Fig.1: Information depth of various analytical techniques (XRF - x-ray fluorescence analysis, OES - optical emission spectroscopy, LMA - laser micro analysis, EPMA - electron probe micro analysis, ESCA - electron spectroscopy for chemical analysis, AES - Auger electron spectroscopy, SIMS - secondary ion mass spectrometry)

It is therefore one of the goals of this paper to show the principles, potential and value of that analytical technique and discuss its possible application for the material characterization of art objects.

PRINCIPLE AND ANALYTICAL APPLICATIONS OF SIMS

Analysis with secondary ion mass spectrometry is initiated by impinging a finely focused energetic beam of ions (e.g. Ar^+, O_2^+ or O^- with a kinetic energy of 1-20 keV) onto the sample of interest. The bombarding ions lose their energy through multiple collisions with atoms in the vicinity of the surface of the target material. These surface atoms receiving energy in excess of their binding energy may be displaced or "sputtered" from the surface. Most of the material leaves as neutral atoms or molecules, but a small fraction is ejected as positive or negative ions. These secondary ions are then extracted into a mass spectrometer for mass/charge separation to provide an analysis of that portion of the material (4-6).

According to equation (1) the secondary ion intensity of an isotope of the element A ($I_{S(A)}$) is proportional to the primary ion intensity (I_P), the sputter yield (S, number of sputtered target atoms of a specific mass per primary ion), the probability of ionization of sputtered atoms (α_A), the concentration of the element A in the sample (c_A), the abundance of the measured isotope ($i_{S(A)}$) and the efficiency of measurement of the generated ion of element A (η_A, composed of collection efficiency, mass spectrometer transmission and detector yield).

$$I_{S(A)} = I_P \cdot S \cdot \alpha_A \cdot c_A \cdot i_{S(A)} \cdot \eta_A \qquad (1)$$

Detection limits of 10^{-19}g can be achieved under optimum conditions. The exact value of the dedection limit depends on the matrix, the chemical state of the element and the surface structure of the sample and are usually higher for oxygen than for argon as primary ions. The sensitivity is also influenced by the purity of the primary beam, contamination of the sample during analysis and by the occurence of mass interferences. Especially at higher mass numbers mainly molecular ions interfer with isotopes of the heavier elements.

The use of a focused primary ion beam provides SIMS with an analytical spatial resolution comparable to that of EPMA. The diameter of a static primary ion beam can be varied usually from less than 5 µm to greater than 200 µm while

maintaining a very large current density. The ion microprobe permits therefore either the analysis of a microdomain by qualitative or quantitative evaluation of the mass spectrum or the acquisition of the element distribution by scanning the ion beam over the surface and recording the areal intensity of a specific mass (ion micrographs).

For art objects and ancient materials this opens the possibility of "in situ" isotopic analysis of micrometer-size phases and extends therefore the spectrum of analytical techniques for dating. Similar to mass spectroscopic investigations which could give detailed informations on the geological origin of some works of art (7) materials can be assigned to certain quarries or the geographical and temporal localization of their manufacture can be investigated.

The analyzed domain at any moment is given by the topmost surface layers and extends to a depth of 1-5 nm (fig.1). It can be also controlled by varying the kinetic energy and current density of the primary ions. SIMS offers therefore the chance to investigate selectively the surface layers of solid samples and as a result of the sputter removal a continuous depth profile of one or more masses can be registered. An intensity versus time profile is obtained that can be correlated into concentration versus depth information but consideration must be given to several factors

- The correlation of time and depth requires reproducibility of the instrumental operation and the knowledge of the erosion rate of the material. This depends on the composition of the layers, crystallographic orientation and the primary ions (energy, beam current).
- For the conversion of intensity to concentration a comparative standard technique - external or internal standard - or calculated correction factors based on a model of the ion production can be used (4, 6). The correlation of intensity and concentration can be a difficult task.

Due to the nature of the sputtering process the material of the surface of the sample is sputtered away during analysis. Therefore under normal conditions used for SIMS the site of impact of the stationary primary beam is normally marked by a conical crater which may have a depth of up to some micrometers after element analysis has been completed. For most samples no other visible phenomena are apparent at the point of impact of the primary beam.

The analysis of conducting samples provides no special problems if the sample is in electrical contact with the sample holder. Contrary, problems arise with nonconducting samples during analysis because of electrical charge build-up on the sample surface resulting from the effects of the charged primary ion beam used for sputtering. To overcome these problems it is convenient to use a negatively charged primary ion beam for sputtering since this has been shown to avoid the electrical charging of the sample. It is therefore desireable to coat insulating samples with a 10 to 20 nm thick layer of carbon or gold in order to reduce the surface charging. This coating is etched away by the primary ion beam within several seconds and analysis can proceed.

EXAMPLE

As an example for the potential of SIMS the results concerning a weathering process on medieval Austrian window glass are described. Medieval glass produced between 1100 and 1500 AD roughly north of the alps differs profoundly from antique or from later glass with respect to chemical composition. Beechwood ash instead of soda was used that period as raw material for glass production. It introduced large amounts of potash and lime into the glass. Both components and the low silica content of the glass decreased the chemical durability of medieval window glass enormously. This is the reason for all difficulties with the conservation of medieval painted windows. Usually thick corrosion layers containing products such as gypsum ($CaSO_4x2H_2O$) and syngenit ($K_2SO_4xCaSO_4xH_2O$) can be identified and pitting corrosion as initial state of the glass weathering could be detected beneath the corrosion layers or on scarcely weathered panes (8)

Contrary to that type of medieval glass dark green colored window panes in Austrain painted medieval windows show only minor corrosion phenomena (9). In addition to potash, lime and silica this type of glass contains also lead oxide as main and phosphorus and copper as secondary components. In order to study and explain the reason for the comparatively high chemical stability of that glass surface only physical in-situ-techniques can be used since the layers cannot be separated subsequently for chemical analysis. Preliminary investigations by the electron microprobe proved a decreased content of K and Ca at the surface of the glass compared to the bulk (10). An ionic exchange between a proton or hydronium ion and an alkali or earth-alkali ion is the consequence of the reaction between water and glass.

For studying that leaching process and the formed surface layers with SIMS the naturally weathered glass surface was provided with a coating of gold to limit the charge build-up on the sample surface. O^- was used as primary ions with an energy of about 10 keV, beam current of 500 nA and a beam diameter of approximately 50 µm. The scanned area at the glass surface was 250x250 µm and positive secondary ions were collected from a central area of 8 µm in diameter.

Under these conditions the sensitivity of analysis is sufficient and depth profiles of high stability can be obtained. Samples of various dark green coloured window panes were investigated and depth profiles of hydrogen, calcium, lead, silicon, sodium, aluminium and potassium were measured and recorded by cyclic switching of the masses. A typical depth profile of a sample, taken from a medieval painted window of the church in St. Michael/Wachau in Austria is shown in figure 2. The surface of that glass has been exposed to ambient atmosphere for about 500 years. During a sputtering time of about 1 hour and 15 minutes a crater of approximately 3 µm was eroded.

For all samples the characteristic "gel" zone can be observed at the surface where the alkali and earth-alkali elements potassium and calcium are depleted and hydrogen is strong enriched. The depth of penetration of hydrogen or depletion of K and Ca varies from one sample to another and is here about 1 µm thick. At depths beyond 1,5 µm all concentrations approach those of bulk glass. That could be proved by measuring the intensity of the various elements at the cross section of the sample. Within a region of 100 nm from the surface non-glassy corrosion layers of Al, Na, K, Ca and especially Pb must be formed due to their depth profiles. That means that the originally leached out ions react on the glass surface with components of the air (especially CO_2 and SO_2). By using negative charged primary ions and high mass resolution to separate O_2^+ and S^+ a distinct surface enrichment of S and C corresponding to that of Pb could be ob-

served (11). Due to the concentration of CO_2 (ca. 600 mg/m³) and SO_2 (ca. 30 µg/m³) in the ambient air it can be assumed that carbonates and/or sulfates are formed during the weathering at the glass surface. The enrichment of Pb, S but also of Al at the surface of the naturally weathered glass is thought to promote resistance to further weathering of that type of glass in the painted medieval windows.

CONCLUSION

Secondary ion mass spectrometry as an "in situ" technique of the micrometer size range can provide informations on the bulk composition, content of trace elements and isotopes and the distribution of the elements at the surface as well as in the depth of art objects. Such investigations enable conclusions on the original localization, technology and manufacturing of the material and can describe corrosion processes or degradation phenomena on the surface of metals, ceramics or glass.

ACKNOWLEDGEMENT

Dr. G. Stingeder (Institute of Analytical Chemistry, Technical University Vienna), who performed SIMS measurements and Doz. Dr. E. Bacher (Österreichisches Bundesdenkmalamt) for leaving sufficient sample material are greatfully acknowledged.

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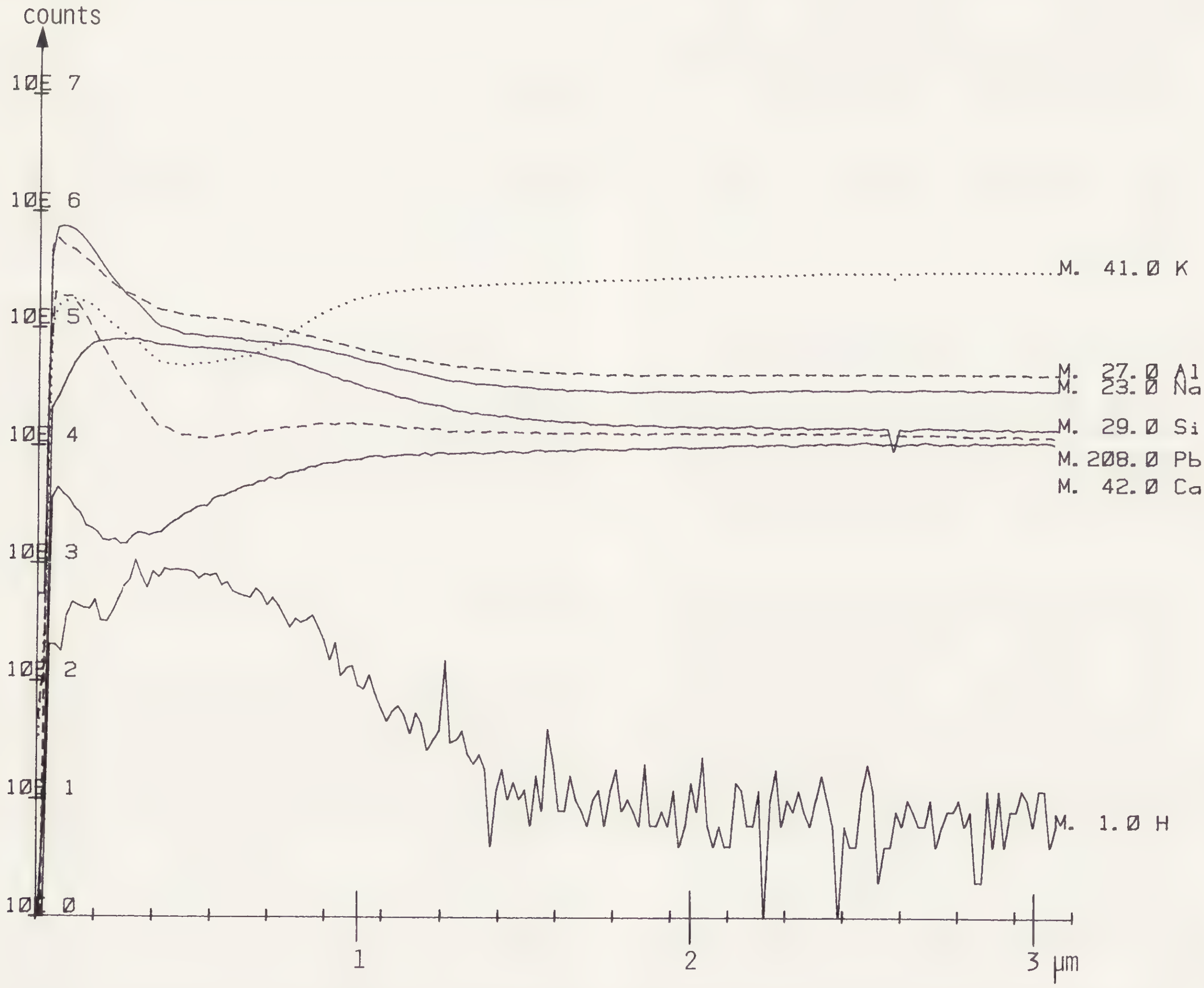

Fig.2: Typical depth profile of hydrogen, calcium, lead, silicon, sodium, aluminium and potassium measured at the surface of a naturally weathered dark green coloured glass sample taken from the medieval painted glass window of the church St. Michael/Wachau, Austria (14^{th} century)

Section 2

Structural Restoration of Paintings on Canvas

Restauration structurale des peintures sur toile

DEVELOPMENT OF A GENERAL PURPOSE TABLE TOP HUMIDIFICATION/SUCTION SYSTEM

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SUMMARY

Investigation of efficient and controllable methods for the relaxation and stablization of paintings led to the development of a humidification/suction apparatus designed for use on top of the vacuum hot table. This apparatus employs a high air volume, low pressure vacuum pump, and can make use of the hot table's heating capability, when necessary. This apparatus puts many treatment options within reach and provides a degree of control not easily achievable with a vacuum hot table or suction table alone.

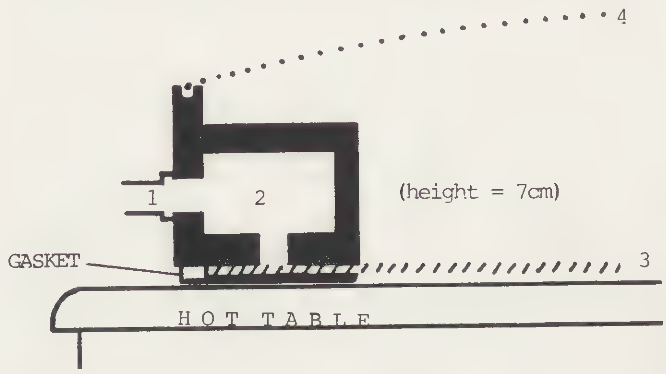
Many conservators have experimented with and used moisture to help in treating problems associated with loss of plane in paintings. For the most part, however, many procedures involving moisture have been carried out intuitively and without the degree of control which most of us consider necessary for optimum safety during treatments. No working guidelines have been presented concerning the practical use of humidification in the treatment of specific painting problems. Only relatively recently have we begun to understand the effects of relative humidity and temperature on the different layers of a painting's structure.[1] Although many of the initial conclusions are based primarily on experimentation using prepared samples, they cannot be ignored, in that they do suggest important working parameters for the use of humidification in conservation treatments.[2,3]

Our own interest in this subject has arisen as a result of various treatments which we have carried out at the Philadelphia Museum of Art and as a result of our desire to be able to perform precisely controlled humidification treatments and membraneless relaxation and linings routinely, we began a thorough investigation of the work of Danish conservator, Bent Hacke. Mr. Hacke has been a pioneer in the investigation and use of such procedures for more than fifteen years. Our intention was to design and build a suction-table type apparatus, based on the principles of Mr. Hacke's design, to be used on top of the hot table, utililizing a high air capacity vacuum pump and allowing precise relative humidity control. This design would both save space and utilize the hot table's heating capabilities. Mr. Hacke had built such units with moderate success. He pointed out the problems he had encountered in adapting his design for use on a hot table. He believed that in order to heat the work surface to even low temperatures of say 100° or 110°F, the hot table would gave to be brought to extreme temperature for heat to radiate through the air chamber and lattice structure and perforated metal plates.

Keeping the lattice structure of Mr. Hacke's design from sagging into the air chamber during air evacuation was also a problem.

In the course of a critical evaluation of the design, the need for the air chamber, lattice grid and associated structural members of the existing design were called into question by our consulting engineer, Bill Maxwell. We decided that the elimination of these portions of the table simplified the design, for two basic reasons, it increased its efficiency and expanded its range for treatment without limiting any of the for which the table was originally designed.

The reasons influencing our design considerations not necessarily in order of importance were: one: economics- since most conservation facilities already have in their inventory a working vacuum hot table it became a design goal of the Philadelphia Museum of Art to utilize as many structural, mechanical, electrical, cost and space saving features of this devise as were practical without sacrificing performance; two: consistent and reproducable conditions- the single most important feature of our design objective was a capability to introduce a predictable and repeatable environmental condition with the devise which in addition to its obvious practical advantages also allows for more comprehensive quantified reporting of techniques and results for the benefit of the profession at large.



1. Connecting Piece to Vacuum Pump and Humidification System
2. Air-Channel
3. Fine Mesh Screen
4. Humidification Membrane

The cross section illustrated above is our Table Top unit showing the simplified design. What remains is the square metal channel through which air is evacuated or humidified positive pressure air is introduced around the table's perimeter. The holes drilled in the underside of the channel are of different size and spacing, depending on their distance from the point of final air extraction, to achieve an even air draw. The humidification and suction functions cannot, of course, be performed simultaneously. The diagonal dashes represent an extremely fine mesh screen which permits lateral air flow to the channel. This screen rests directly on the hot table surface. The square gasket at left creates a seal on the hot table surface. The dotted line represents a membrane that can be put in place to create a humidification chamber. When humidified air is introduced into the chamber producing positive pressure, the membrane immediately assumes a slightly domed configuration which encourages any droplets of moisture which may form on its inner surface to roll down the sides, avoiding any contact with the painting. The membrane is easily removed or replaced to perform relaxation or lining procedures as necessary.

Another design objective of ours, which had also interested Mr. Hacke, was the development of a precisely controllable humidification system. The design which eventually resulted from our investigations will quickly achieve and maintain any desired relative humidity ±3% at temperatures up to 110°F.

Overall, we are extremely encouraged by our results and the performance of the table. The ease and efficiency with which the table can be operated and controlled makes a wide range of treatments possible. The high air flow vacuum pump provides controllable pressures without the use of a membrane. The thin, virtually non-textured screen used in place of the air chamber and lattice grid allows efficient air evacuation, making elaborate hot table preparation unnecessary. Both of these

advantages, and the proximity of the screen to the heat source, permit a wide range of hot, as well as cold, lining techniques to be performed controllably without a membrane. The ability to achieve and maintain a specific relative humidity at a specific temperature for any period of time, with a continual record of the environment, will permit thorough practical investigations of the parameters of moisture vapor treatments. As the design was intended for use on a conventional hot table, it may only be necessary, in many cases, to replace an existing low air capacity pump to utilize all of the table's capabilities. A further and perhaps equally important biproduct of our design efforts may be the possibility to treat three dimensional objects and ethnographic materials, many of which are very clearly influenced by conditions of temperature and humidity. Preliminary experimentation in reintroducing moisture to desiccated three dimensional objects and or fabrics show marked promise. We are not suggesting any rule book for its use or the promise of miraculous new results. It was designed and built to help perform more safely and efficiently procedures which we have found to be useful and effective.

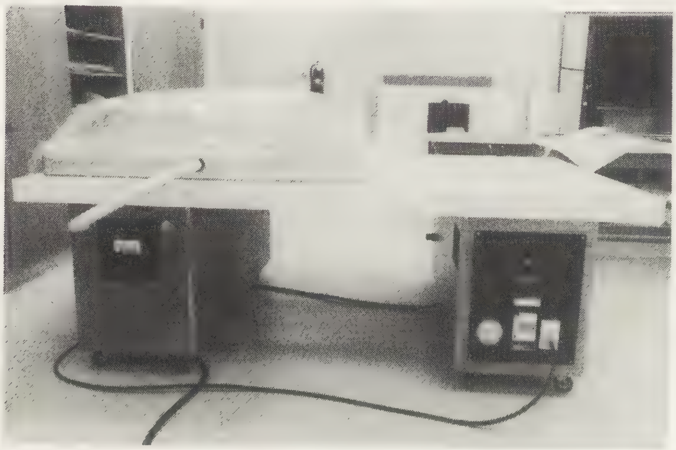
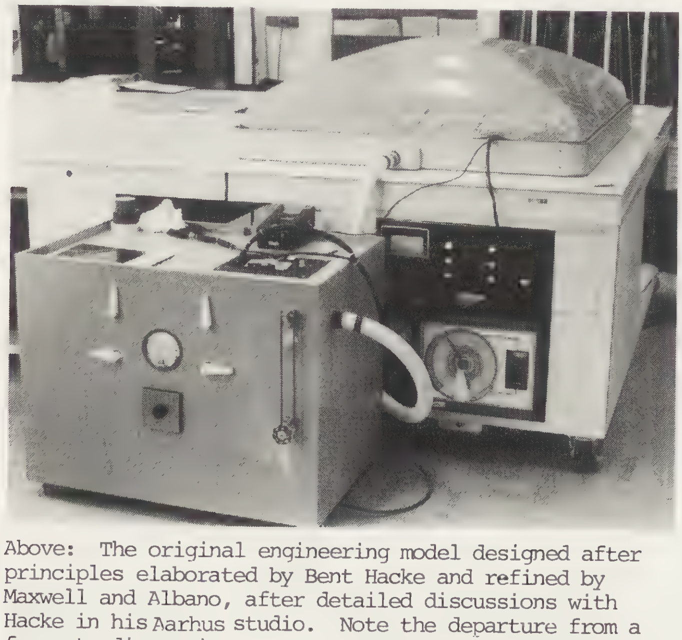


Photo above depicts the second generation table top humidification suction devise (VHT-101) with mechanical and electronic components built into a traditional vacuum hot table (VHT-100). Temperature, humidity and vacuum controls are an integral part of the devise. The only separable part is the actual lightweight table top unit which stores conveniently in a painting storage rack.



Above: The original engineering model designed after principles elaborated by Bent Hacke and refined by Maxwell and Albano, after detailed discussions with Hacke in his Aarhus studio. Note the departure from a free standing unit to a more cost effective system utilizing the capabilities of the traditional hot table.

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Ackowledgments: I would like to thank Marigene Butler, Head of Conservation, for her continual support on all levels of this project. Mark Tucker, Associate Conservator of Paintings for his insightful suggestions and assistance. Bill Maxwell for his objectivity, knowledge and expertise so congenially applied.

THE FINAL REPORT ON A STABILIZING TREATMENT FOR AN UNUSUALLY LARGE AND HEAVY CONTEMPORARY OIL PAINTING ON CANVAS

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SUMMARY

Milton Resnick's Saturn 1976, NGC #23,138 oil on canvas 2.47m H x 3.00m W, 95 Kilos; painted to a high spiky impasto with a depth of 2.0cm in places. The surface of the work could not be touched without detriment. Preventative conservation in this case, was agreed to by the artist and the curator. The logistics of handling a work of this size and weight, posed unique problems which were thought to be best dealt with first in a mock-up treatment. A reduced version, approximately one seventh the size and weight of Saturn 1976 was painted with similar materials, in the laboratory. Tests were then run on the mock-up to ascertain which method best suited these peculiar problems. An adapted method of V.H. Mehra's cold-lining technique was used on the simulated Resnick painting, using Plextol B500 as the adhesive, to attach the painting to a solid fibreglass-skinned Hexcel aluminum honeycomb panel, using a compressed nylon interleave. The results were encouraging. The treatment has now been completed on Saturn successfully; so much so, that the artist has given another of his paintings, That Elephant 1979, 3.00m H x 4.87m W, 113 Kilos, free to the NGC, if this conservator could provide a similar treatment as was completed on Saturn. That Elephant has been rolled for three years.

BASIC DESCRIPTION OF THE PAINTING

Artist:	Milton Resnick (American)
Title:	Saturn
Date Painted:	1976
Medium:	Oil on Canvas
Dimensions:	2.47m H x 3.00m W
Thickness of Impasto:	2.0cm
Weight:	95 Kilos

CIRCUMSTANCES OF ACQUISITION

At the National Gallery of Canada (NGC), historic works being considered for acquisition, are always brought to the Restoration and Conservation Laboratory (RCL) for examination. This has not always been the case with contemporary works. In the case of Milton Resnick's Saturn 1976, the curator of contemporary art[1] was alert to the possible conservation problems presented by such a heavy layer of paint supported only by canvas and a very light-weight wooden strainer. He decided that the work should be examined and reported on by RCL prior to acquisition.

The initial problem was the transportation of the painting from New York City to Ottawa for viewing by the Acquisitions Committee and examination by RCL. In any orientation, travel could seriously damage the painting. This problem was temporarily solved by inserting soft urethane foam, held in place by corrugated cardboard behind the painting, and just thick enough to keep the canvas and paint layers as steady as possible. The painting travelled by a National Museums of Canada truck at an angle of approximately 30°.

NATURE OF THE CONSERVATION PROBLEM

Examination in the laboratory revealed the following:

The paint layer of Saturn is of a general overall homogeneous dark shade with pure colour glistening here and there upon closer inspection. The impasto is unusually high, 2.0cm in places and somewhat brittle. The paint was applied by brush over a period of time. This gives the earth-like surface which is characteristic of Saturn. While working on Saturn, the artist, Milton Resnick, brushed the paint[2] around onto the tacking margins; especially the two verticals. On sections of these painted edges, the paint had opened a little, indicating possible restretching of the work after completion. Apparently this was the case, as the artist usually asks for his original stretcher back after the painting is sold; the dealer having to substitute another.[3] The strainer on which the painting was supported was a light-weight soft wood, probably white mahogany. It was built in two main sections, joined down the centre. The strainer was totally inadequate in supporting the weight of Saturn.

Saturn is painted on a commercially-prepared linen canvas which is of the highest quality,[4] and has an oil-based ground which is quite stable. But the canvas support had already begun to undulate from the gravitational pull of the great weight of paint on the front of the canvas. These undulations were particularly visible in the lower third of the work. The painting had been signed on the back of the canvas by the artist in black, in the upper left quadrant, "↑ Saturn Resnick 1976".

The painting was in a very unstable condition, and unless preventative conservation was carried out to help support the weight of the paint in a more realistic manner, maintenance would become an ever-increasing problem. The paint would, in all eventuality, have detached itself from the canvas support. The areas of undulation were the most vulnerable parts of the painting, as it is there that compression cracking and cleavage would have begun. The paint could, at the time, accomodate the undulations and movement of the canvas, but it would have tended to become quite brittle in the years to come. The canvas becoming less and less flexible - the undulations becoming more fixed. As mentioned, the strainer was completely inadequate for supporting the size and weight of Saturn. Whenever the painting was re-hung or moved to storage, it concaved in a most alarming manner and tended to leave little trails of chipped paint behind.

A meeting was held between the curator, the Head of RCL and the conservator[5] to discuss three treatment proposals for preventative conservation of Saturn, prior to the acquisitions meeting. Estimates on cost of materials and conservator's time were included in the three proposed treatment reports sent to the curator. The three methods were then discussed at length. The curator decided on the third major treatment presented, suggesting that a more detailed report from one of the three proposed treatments should be discussed, if the painting was bought by the NGC. Milton Resnick was approached to find out what his attitude was: he had no objections. As a result of the RCL proposed treatment report at the acquisitions meeting, the curator was able to negotiate with the artist's dealer, the price for the painting to be bought by the NGC. The asking price was calculated against the cost of materials and the conservator's time to complete treatment. The NGC bought Saturn at the negotiated price in June 1978. More detailed research was begun on the proposed three preventative treatments.

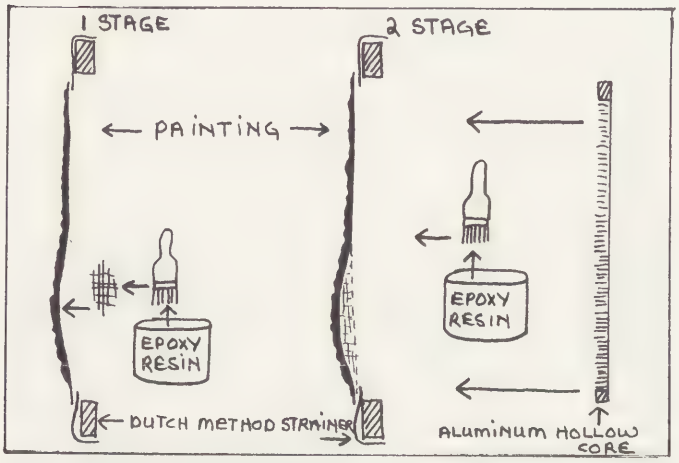
DEVELOPMENT OF PROPOSALS IN MORE DETAIL FOR TREATMENTS

The Curator, Head of RCL and the conservator met again to discuss more fully the treatment proposals. The first treatment discussed was:

1. Minimal Treatment:

   The minimal treatment presented was to have a much stronger expandable stretcher made of clear pine

with four crossbraces and four vertical braces. This would then have cotton duck canvas stretched over it and have a light spraying with disinfectant; probably a 1% solution in water of Dowicide B. Saturn would then be taken from its strainer and attached to the new stretcher with staples on the tacking margins over the cotton canvas, but free of the original canvas. This would hold the undulating of the canvas in a more secure fashion. But in the long-term, this solution is not really worth the couple of years grace we would have gained before having to attach the painting more permanently to a solid support. The less a work of art is worked on, and moved about, the less the intention of the artist is subjected to interpretation and possibly misrepresented.



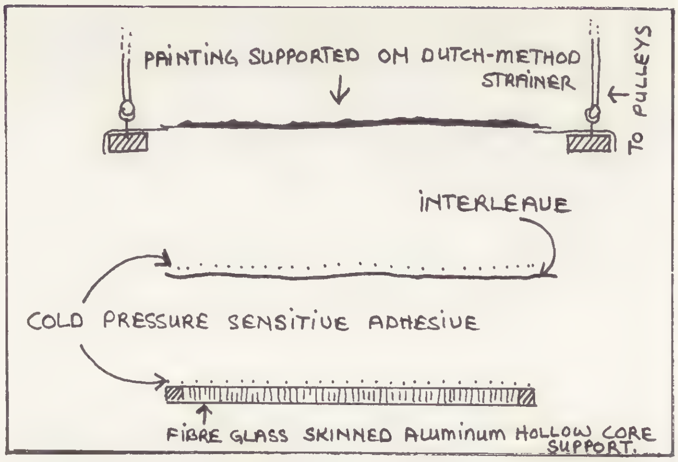
PROPOSED MAJOR TREATMENT - IRREVERSIBLE METHOD

2. Major Treatment - Irreversible Method:

The second treatment proposal was a major irreversible method which has not, to my knowledge, been attempted in a museum laboratory to a museum painting. It was suggested that a solid support be attached to the reverse of the painting directly. This would be done by applying fibreglass sections with epoxy resin adhesive in a building-up process to the back of the vertically-supported painting on a dutch-method strainer; then attaching the painting and fibreglass resin to a honeycomb panel with the same type of epoxy resin. This would "freeze" for quite some time the convolutions and strains which the canvas has acquired since being painted. In other words, the fibreglass skin next to the painting would maintain the shape of the painting as it was acquired by the NGC.

A second irreversible method could have been considered. A solid support of fibreglass skins with an aluminum Hexcel honeycomb centre, could be built separately using the thixotropic epoxy resin as the adhesive. The reason for using a seperately-made flat fibreglass support, is that the painting would revert back to the plane it was originally painted in; as the work is only four years old and still flexible, it could return to its original plane quite successfully, especially if the painting was taken off its present strainer and left lying flat on its back for several weeks before being adhered to a new support.

We were lucky that, at this time, the Environment and Deterioration Research Laboratory of the Canadian Conservation Institute, happened to be doing extensive tests on many epoxy resin adhesives. Degradation testing had been completed with the indications that thermalchemical deterioration and tensil strength are related. This had a direct bearing on the specific use of epoxy resins in this proposed treatment for Saturn. With the indication that epoxy resin adhesives are not as permanent as generally assumed, they should only be used in extreme cases where no other adhesive method is available. An adhesive should be used which has greater resistance to loss of adhesion.[6]



PROPOSED MAJOR TREATMENT - REVERSIBLE METHOD

3. Major Treatment - Reversible Method:

With the third proposal, a Hexcel aluminum hollow-core panel with either aluminum or fibreglass skins was recommended as the support to add as little weight as possible to the weight already there. One would not be able to obtain a panel 247m x 3.00m without paying an extremely high price; it would need to be constructed in the laboratory. An inter-layer of linen would be required to facilitate the possibility of removal of the painting. A solid support was chosen as the best method of arresting and holding the inevitable convolutions of the canvas and cracking of the paint which were occuring even then, though the painting was only four years old. Presumably, the vibrations which the painting had already undergone on its journey by truck from New York to Ottawa, had caused the beginnings of cracking and cleavage (even though this was lessened with the foam and cardboard which had been attached to the back of the painting).

A pressure-sensitive adhesive such as CM Bond PSVA Resin, which is a vinyl acetate acrylic copolymer emulsion, or Plextol B500, an acrylic methacrylate copolymer emulsion used by V.H. Mehra in his cold table linings, could be used as adhesive; the tensile strength of these would be tested before use.

The third method, was chosen by the curator after discussion took place on all three treatments. This method was chosen because it was reversible and seemed to offer as many of the advantages of the other two and none of the disadvantages. The artist was consulted again at this time - again, he had no objections.

It was decided to try an adapted version of V.H. Mehra's cold-lining adhesive. Mehra was approached concerning the adaptation of Plextol B500 to the special needs of Saturn. He responded with enthusiasm and very valuable input.

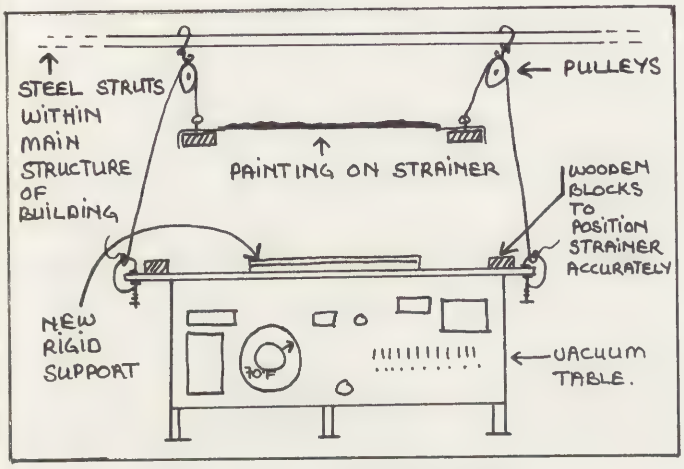
SIMULATED PAINTING AND ITS TREATMENT

It was thought that the best way to become familiar with the very special problems Saturn presented, would be to produce a simulated version one-seventh the actual size of Saturn, and have testing of the major reversible method carried out upon it. A simulated painting was completed in the laboratory in March 1979, with the information supplied by the artist, three years after the original. The rigid support was made according to Webster and Mecklenburg's instructions,[7] but using fibreglass skins instead, because of their greater impact resistance;[8] and, it is believed, the thermal co-efficient of expansion of the fibreglass skins (the resin being the important factor) is closer to the fibre of the canvas support than aluminum by a factor of 10.[9] Compressed nylon inter-leave (Pellon),[10] was adhered to the new rigid support with Plextol B500 mixed with 5% water, adding 10% Toluene in blender. To facilitate the handling of the simulated painting, it was removed from its stretcher and 20cm wide canvas

extenders were sewn to the perimeter of the tacking margins which were then used to staple onto a dutch-strainer.

Pulleys with ropes capable of supporting the weight of simulated Resnick and its dutch-strainer, were attached to metal struts in the ceiling above the large hot vacuum table. This was constructed to facilitate the lowering of the painting and its strainer onto its new rigid support. The working time of the adhesive was an important factor in joining the work and its new support, as the adhesive dries quickly.

The sequence of the proposed treatment was as follows:



SET UP FOR TRIAL RUNS ON SIMULATED PAINTING

FIRST TRIAL RUN

1. Blotting paper was laid on the aluminum surface of the vacuum hot table, then a layer of polyethylene film (Mylar) 0.5mm thick.

2. A heavy cotton canvas was laid over the mylar and the table, leading from the two vacuum outlets. This was to facilitate evacuation of the air under the rigid support.

3. Plywood boards the size of the simulated painting were used to raise the new rigid support to the inner depth of the dutch-method strainer, 4.0cm.

4. Before any adhesive was applied, the dutch-method strainer and simulated Resnick were positioned accurately on the new rigid support and with the use of wooden blocks secured into position.

5. The stretcher and the simulated Resnick were then raised by the two pulleys to approximately 1m above the vacuum table.

6. The compressed nylon on the rigid support was coated with the adhesive Plextol B500 by roller, prepared as previously described, but with 2% water and mixed with 10% Toluene. The adhesive was left for half an hour to dry; it was then sprayed with Toluene to reactivate the adhesive. The ventilation system within the laboratory was activated and masks were worn.

7. The simulated Resnick was then lowered down onto the new support.

8. To avoid pressure on the spiky surface of the painting, the covering mylar sheet (0.5mm) had an opening cut into the centre so that it covered only the table and the tacking margins of the work. The painted surface of the simulated Resnick was considered thick enough to act as part of the seal.

9. The mylar was attached to the simulated Resnick along the tacking margins with double-sided tape. The staples holes already having been sealed with masking tape.

10. The vacuum was then applied with three 1/16 h.p. pumps operating to capacity for two hours. Because the painting surface was not covered with the mylar vacuum pressure could not be monitored well, but pressure could not be high.

The first trial did not result in good contact between the rigid support and the simulated Resnick. The painting was removed from the rigid support easily with the use of a steel straight edge. The work was then re-attached to the dutch-method stretcher as described previously.

SECOND TRIAL RUN

1. The second trial run was prepared as before, but applying the Plextol B500 adhesive with a roller to the back of the simulated Resnick, as well as the new support.

2. Corrugated polyflute[11] was laid on top of the canvas bleeder, under the tacking margins of the simulated painting to help evacuate the air more effectively. Continuing as in the first trial, contact was much better and much more evenly distributed, but was still inclined to come away, especially along the perimeter, due, it is thought, to the tenting action of the canvas over the edge of the rigid support. Where contact had been achieved, it was good. A third trial was considered necessary, and in preparation for this, the simulated Resnick was removed a second time, again using the slim steel straight edge. It was then re-attached to its canvas strips and the dutch-method stretcher.

THIRD TRIAL RUN

1. The rigid support was drilled with 2mm holes on a five centimeter grid system. This was to facilitate the evacuation of all air and to gain closer contact between the support and the painting. The 2mm holes helped to remove excess moisture and solvent from the adhesive. Three vacuum 1/16 h.p. pumps were left at full capacity for 24 hours (with hourly checks).

This third trial worked well, although there was one area where poor contact was overcome by carefully placing weights on the front of the painting. The simulated Resnick was taken to the Canadian Conservation Institute and put in an environmental chamber where temperature, and RH changes tested the adhesion. The painting remained secure.[12]

Another meeting with the curator, the new head of RCL[13] and the conservator was held at this point, and the three trials were discussed at length considering the simulated Resnick itself, and how it had reacted to the treatment. It was then decided to go ahead with the treatment on <u>Saturn</u>. The treatment was very similar to that carried out on the simulated version.

FINAL TREATMENT COMPLETED ON SATURN

The large hot vacuum table was covered with a layer of heavy linen, to protect the surface of the table. The painting was then laid on the table. The painting could be flexed very easily, which shows quite clearly how inadequate the dealer's strainer was. The strainer was then removed by sliding it from under the painting, leaving the painting to lie flat for some weeks. The lower third of <u>Saturn</u> being the most affected with a large bulge; to encourage the canvas to lie flat, weights were used. The painting was left for about a month this way, the weights being moved about gently, as seen fit.

1. The canvas extenders were then sewn on, with the use of a small sewing machine, on a stand with wheels on it. <u>Saturn</u> was then moved to a temporary table and attached to the large dutch-method strainer. It was left in that position for several months, supported by the table and the strainer. It flattened out well.

2. The new rigid support was constructed, as previously described, on top of the large hot vacuum table and finished with 0.02cm holes drilled at approximately 4.0cm intervals, more at the perimeter edges of the rigid support.

3. The compressed nylon interleave was attached using Rhoplex AC 634. That and the new rigid support were raised up from the table (using wood strips) to help evacuate the air more efficiently when the painting was finally attached under vacuum.

4. The painting was then aligned on top of the new rigid support. Wooden markers on trestles located at each corner of the large hot vacuum table were used to hold the dutch-method strainer in an accurate position.

5. At this point, the double-sided tape was attached to the tacking edges of the painting which would hold the mylar envelope in place.

6. About eight people were required to coordinate the final laying down of Saturn to its new rigid support. The dutch-method strainer with Saturn attached was raised by four pulleys attached at each corner of the stretcher to approximately 2m above the hot vacuum table and the rigid support surface.

7. The compressed nylon was rolled with the adhesive Plextol B500, prepared as previously described. The adhesive was left to dry. The adhesive tended to fill the 0.02mm holes, which had to be re-opened using a pointed tool.

8. Saturn was then realigned to its new rigid support. The wooden markers nailed to the tops of the trestles keeping the painting in position.

9. The painting was then lifted up again and left at an angle of 45° to facilitate the spraying of the adhesive surface with iso-propanol to reactivate it. All ventilation systems were on and masks were worn.

10. The painting was left for 15 minutes, then lowered onto its new support. The cotton-duck edge extenders were quickly cut away, and the dutch-method strainer pulled to the ceiling. The mylar was attached with double-sided tape to the edges of the painting and sealed, the vacuum was then turned on. A water gauge being attached to take readings of the vacuum pressure. The vacuum was supplied by a large wet-dry vacuum cleaner borrowed from the NGC Workshop. The vacuum cleaner was left on for four days and was checked by the security guards every 12 hours, when we were not in the lab.

After the treatment was completed, the adhesion was tested by delicately touching the surface of the painting; a bridge over the painting was used to support the conservator while this was done. The adhesion was found to be good. Handles were then attached at the back of the painting to facilitate handling. Two retractable bolts were attached at the back of the painting at the bottom edge, so that when it was resting on the floor, the bottom edge of the painting was protected from abrasion; yet was not noticeable in the normal viewing position.

Saturn has been on display for about two years, with no apparent changes being noted.

DONATION OF THAT ELEPHANT TO NGC

In May 1982, Milton Resnick expressed a desire to donate one of his paintings to the NGC. This is a painting somewhat larger than Saturn: its dimensions being 3.0m H x 4.87mW and weighing approximately 113 kilos. It was prepared in much the same way as Saturn except that he used his own home-made oil paint, made with cold-pressed linseed oil and dry pigment. Resnick used the best of ingrediants and made the paint according to USA paint standards. The colours of That Elephant, as he has named the painting, are more ochre with warm flecks throughout. Obviously, Saturn would benefit from the addition of this later work to the collection. A curator and conservator[14] went to Resnick's studio to look at the work from an aesthetic and physical point of view. The painting was rolled and had been for the past two years. On inspection at Resnick's studio, its condition appeared quite good.

Resnick donated That Elephant to the NGC, largely to ensure preservation of the work, and as he was impressed with the consideration and conservation treatment which his painting Saturn received when bought by the NGC in 1978.

As far as the NGC is concerned, this is a very rare occurrence, as it is NGC policy not to accept gifts from living artists of their own works.

That Elephant arrived at the NGC in January 1983; it was unrolled in the basement of the NGC as it was decided that the main studio could not accomodate such a large painting for any length of time. That Elephant at time of writing, is undergoing a gentle flattening process which is estimated to take four to six months.

The curator,[15] conservator and artist re-thought the entire treatment carried out on Saturn, considering other possible alternative treatments for That Elephant. It was decided that as That Elephant has been rolled on a tube for nearly three years, attaching it to a rigid support would be the best approach. It was thought that the "memory" of the canvas from the tube would almost inevitably re-occur; so given the alternatives, we have decided to attach That Elephant to a rigid support in a manner similar to that completed on Saturn.

1. Brydon Smith, now Assistant Director, Collections and Research, NGC.

2. Lefranc; information from the artist.

3. Information from the artist.

4. Specially ordered and imported from Belgium.

5. Brydon Smith, Ian Hodkinson, Marion Barclay.

6. Research was carried out by Jane Down, Environment and Deterioration Research, CCI.

7. Studies in Conservation 22 (1977) pp. 170-176.

8. Excelite fibreglass panels, series 400, 4 oz. per square foot. Graham Products Inc., Inglewood, Ontario, Canada.

9. Building construction Handbook, F.S. Merritt, pp. 3-8.

10. Pellon, a mid-weight all bias polyester interleave.

11. Crystaplex, known colloquially as polyflute; made up of 90% polypropylene and 10% polyethylene. Available from Crystaplex Plastics Ltd., Canada.

12. Jane Down, Canadian Conservation Institute.

13. Ursus Dix.

14. Jessica Bradley, Assistant Curator of Contemporary Arts, NGC, and Marion Barclay.

15. Brydon Smith.

THE NEW STRESS TESTS ON CANVAS PAINTINGS AND SOME OF THEIR IMPLICATIONS ON THE PRESERVATION OF PAINTINGS

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SUMMARY

Stress measurements on canvas paintings and models of stretched painted canvas have shown paintings to be extremely sensitive to changes in environment, and particularly to the small changes induced by cycling environmental controls. An attempt to measure the changes in tension caused by treatments, and their implications on the preservation and conservation of paintings is described.

Canvas has been commonly used as a support for paintings since the sixteenth century because it is lightweight, portable, available in large sizes, and can be mounted under tension to provide perfectly smooth surfaces. However, the cotton or linen normally used have the major disadvantage of being subject to large dimensional changes. These dimensional changes, or deformations, become detrimental when they are incompatible with the paint layers or the supporting stretcher. Cracking and cupping of the paint is evidence that the canvas and paint layer have different deformation characteristics. Sagging and buckling of the canvas result when the initial tension in the stretched canvas is lost. These examples of distress in the painted surfaces are not due solely to the deformation of the paint layer, canvas, or stretcher but rather due to the incompatibility between these components. A better understanding of these deformations and their characteristics is necessary in order to eliminate, reduce, or correct them. This paper will concentrate on the behavior of actual canvas paintings held by stretchers, and on tests conducted by the authors over the last three years on samples simulating such conditions.

The tests were prompted by the excellent state of preservation of panorama paintings the world over which called for an explanation (1). The enormous size of these paintings made their dimensional changes obvious to the unaided eye. It was easy to measure and document them with a time-lapse camera. After several months of measurements, it was found that while the changes in dimensions were triggered by environmental conditions, it was never-theless impossible to establish a direct correlation. It was then decided to devise a testing program, whereby changes in temperature and humidity could be controlled. As the tests progressed, the design of the testing apparatus was often improved to give more exact and realistic measurements (2).

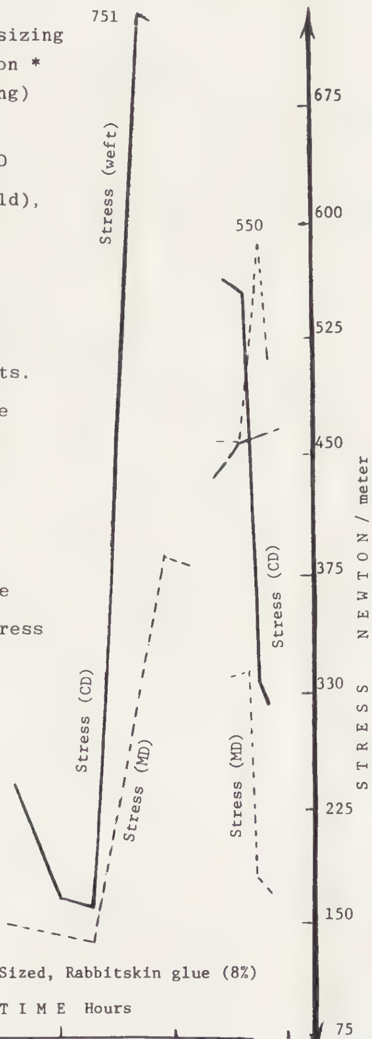
The objective of the experiments was to observe the relationship between stress and deformation in painted and unpainted canvas under variable environmental conditions. To achieve this objective, a stress tester was built which operates in the following manner: A square canvas sample is mounted horizontally in a plywood enclosure which, when covered with a plastic sheet, forms an environmental chamber. Fans, heaters and air-conditioners, connected to the chamber, create the desired temperature and humidity conditions. These are monitored by the digital temperature/humidity sensor. A series of parallel fiberglass threads connect each side of the canvas sample independently to an open structural frame with a flexible epoxy adhesive. The fiberglass threads serve to restrain the canvas in the direction of the threads, but permit unrestrained motion perpendicular to the threads. In this way, it is possible to subject the canvas to controlled, uniform stresses and strains in two directions simultaneously. The canvas can be stretched to any desired level in each direction by tightening the threaded rods which connect the elements of the structural frame. A load cell in each direction measures the force exerted by the canvas in that direction and displays the result on a digital readout. With this apparatus it is possible to measure the stress in each direction of the fabric simultaneously with the temperature and relative humidity in the air in the environmental chamber.

The enormous sensitivity of the canvas to the smallest changes in the environment became apparent even before our testing arrangement was completed. The canvas reacts before the best electronic thermometers and hygrometers subsequently installed which read to 0.1°C and 1% RH could register the change. Another surprise was the strength of the reaction: a rise or drop of 1-3°C could cause a change in tension between 20 and 50%. However, while the reactions were clearly caused by environmental changes, no rule could be found as yet which would make it possible to predict these changes. The search for such rules obscured the fact which we now believe to be the most important finding of our tests so far: <u>we have a new, extremely sensitive diagnostic device for the reactions of canvas paintings to outside influences</u>. This new device makes it possible to magnify and analyze the reactions of the canvas to any treatment it received, just as a magnifying glass, or microscope, enables one to examine the structure of a material which is too small, or obscure, to detect by the unaided eye. The explanation could be found in the testing arrangement. By suspending the canvas in the same way as it would be within the surface of a painting while eliminating the interference of the stretcher, we could measure the effects which a given local treatment would have on its surrounding areas, or on the entire painting. For example, to test the hypothesis that glue treatments introduce tensions in the surrounding paint layers, the sample was coated with glue and the resulting increase in tension measured (Fig.1a) (In most cases, a considerable and lasting 200-300% stress increase). Similarly, the sample could be painted with different priming compositions, and their respective effects on the reactions of the canvas investigated (Fig.1b), not only under standard conditions of a museum environment (21°C and 60% RH) but also through the whole range of conditions to which a painting might be exposed during transport, and in treatment on a hot table or with a heated spatula (Fig.1c). Similar tests could be run for different lining methods. Cracking, cupping, treatments with solvents, all show distinct, typical, and measurable reactions on the new tester, which wait to be interpreted.

But this was not the original intention of the new tester which was built to measure the effects of environmental changes, heating and air-conditioning on paintings. For the first time, these effects can be measured directly on model paintings, and the best conditions determined. These measurements show that experience and common sense have not been too

far off in the choice of the optimal conditions for galleries. At about 21°C and 50% to 60% RH the stress variations caused by environmental changes seems to be at their lowest level, as compared, for instance, to 18°C and 40% RH, or to 25°C and 30% RH. However, the technical methods to achieve a steady level of 21°C and 60% RH seem far from perfect. Small fluctuations of heat and humidity normally occur even in buildings with the best climate controls, and these seem to be much more detrimental to paintings than the prevailing thinking would indicate. Of special concern in this respect seems to be the frequent cycling of heaters, air-conditioners, and other environmental control devices which appears to magnify the effect of temperature changes.

Fig. 1a Effects of Glue-sizing on Canvas Tension * (Schematic Plotting)



The stress rises in the CD (weft) direction from 150N/m to 750N/m (five fold), and drops to about 330N/m upon drying.

After complete drying and return to the conditions at the beginning of the test, the stress rises to 500N/m and remains high during the subsequent tests.

The impregnation with glue raised the tension in the canvas for all but high humidity conditions and, for this reason, made all stress changes due to humidity more violent.

Figures 1a, 1b, and 1c are all in the same scale in order to emphasize the stress increase due to sizing.

* Stress is given in Newtons per meter, which is roughly 1 g/cm. 100 g/cm = 9 oz/inch of stress, or a lightly stretched canvas.

Measuring the considerable changes in stress which occur in paintings, and the modifying effects of treatments, points out the forces contained by the cohesive strength of the different components of the laminate. As of this writing, we had little chance to explore the mechanism of the reactions of the painting to such stress changes, nor have we been able to put our results into a mathematical form which would make it possible to construct a universal model. However, some of our findings for a variety of situations are listed below:

1) Increase in Tension (Stress) in the Canvas

1.1 Causes the canvas to get more rigid and to resist deformation by outside agents, such as impact, as well as shrinkage or expansion of the paint,

1.2 Causes the canvas to become overstretched, creep, and lose tension.

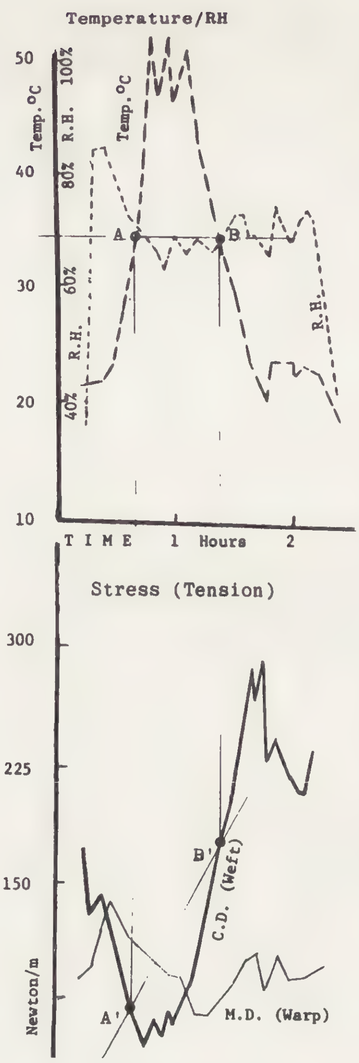


Fig.1b

Hot-table Simulation (Humid Conditions 60-70% RH)

The top part of the graph gives temperature and RH, the bottom part - the resulting stress changes.

In spite of the high humidity, there is a considerable rise in tension during the cycle.

Consequently, the stress rises after each fluctuation until a maximum is reached: Point A (before the test) has approximately the same temp./RH as point B (after the test), 33°C and 68% R.H.

The tension in A' is ca. 60N/m, and in B' - ca. 180N/m.

The cycling at 50°C simulates the action of a thermostatic control.

As can be seen from Fig.1b and Fig.1c, the short-term effect of humidity fluctuations on stress is slight.

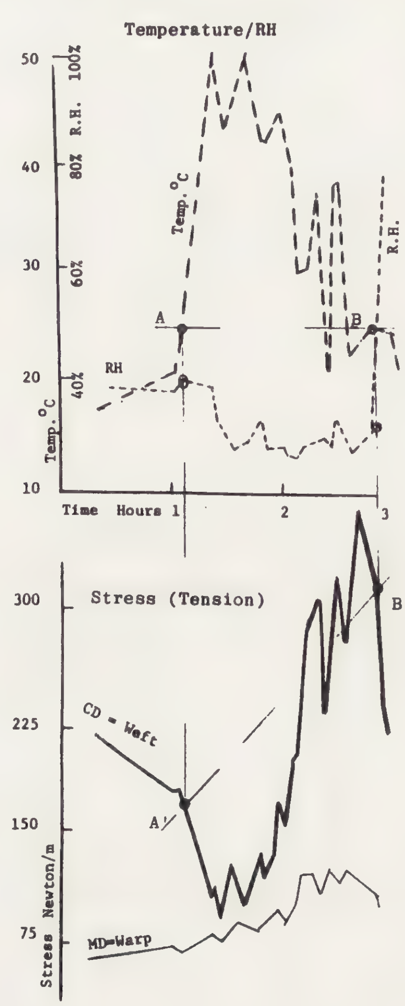


Fig.1c

Hot-Table Simulation (Dry Conditions 15-20% RH)*

Unprimed Linen (basket weave)

The rise and fall in stress (tension) are not much different from those in humid conditions, but the values are slightly higher, and the amplitude of the fluctuations is somewhat bigger.

Consequently, the rise in tension during cycling is evident:
A' = appr. 160N/m,
B' = appr. 280N/m.

* The same is true for an iron and a heated spatula.

2) Effects of Contraction and Expansion of Paint and Support in a Partially Painted, Unprimed Canvas (Fig.2)

2.1 Expansion of Paint (or Shrinkage of Canvas Causes:
2.1.1 the paint to bulge upwards convexly, and possibly form a ridge, or tent,
2.1.2 the paint to compress, and possibly form shear cracks.

2.2 Shrinkage of the Paint (or Local Expansion of the Canvas) causes the paint to:
2.2.1 come under tension and cup upwards, concavely,
2.2.2 eventually tear and form tension cracks.

2.3 Reduced Expansion of the Canvas Due to Resistance of the Paint Film
2.3.1 causes the paint film to come under tension (with effects described in 2.2.1 and 2.2.2).

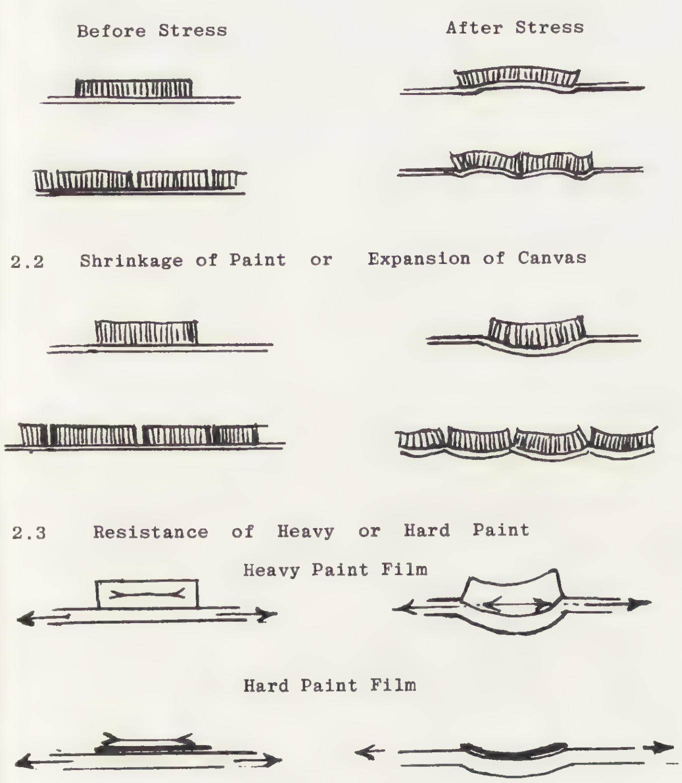
3) Uneven Resistance of Canvas and Paint to Tension (Stress)

3.1 Unevenness of Yarns and Weave causes:
3.1.1 different expansions and contractions during changes in tension,
3.1.2 typical cracks which follow the weave of the canvas.

3.2 Uneven Paint Application
3.2.1 causes the areas of heavier and harder paint to resist tension more than those with thinner and softer paint, or with broken films,
3.2.2 Harder, more homogenous films will be more likely to come under stress as the tension in the canvas changes, and thus will be more likely to crack.

Fig.2 Deformations Caused by Stress Changes in Canvas

2.1 Expansion of Paint or Shrinkage of Canvas



The resistance of the paint to stress can be due to its bulk or high modulus of elasticity. The resulting distortion, however, is dependent solely on its force of resistance.

3.3 Canvas Partially Protected From Environmental Changes
3.3.1 This condition can be created by the stretcher bars, or labels. As a result, part of the canvas expands while another one contracts, leading to movements within the canvas,
3.3.2 Differences in temperature might be caused by dark or light colors, thick or thin paint.

4) Differential Behavior of Canvas Caused by Local Treatment

4.1 Impregnation with glues, or consolidation, can cause similar changes in stress, or strain, as described before, in 3.2.1, 3.2.2, and 3.3.2.

It must be understood that with every added component of the laminate the number of possible variations grows by factorial progression. Canvas in itself has a structure which is rather complex, and its behavior depends on many variables, such as weave type, weave direction, and previous stress. With every modification, the number of responses increases, and, therefore, the list of possible reactions becomes more and more complicated. The above list, by no means complete, is merely an effort to show a few implications of stress changes and how they can help explain some of the deformations of the paint layer, thus help us in our work.

The effects of tension in unprimed canvas have been singled out because they clarify the results of non-uniform resistance of the canvas-paint laminate to stress. The differences in behavior of a partially painted unprimed canvas and one which is fully primed and painted, while still more complex, is only a matter of degree: for a while, the priming forms a rigid layer which prevents excessive movements and creep of the canvas. However, our tests have shown that,upon aging, and with the development of cracks, the canvas returns to its own, unmodified behavior. Each "paint island", surrounded by cracks, behaves like a paint film on unprimed canvas with its violent movements and tendency to sag and distort.

It is at this stage that lining takes over the functions of the original priming, and protects the brittle film from violent movements. Measurements on the 100-year-old Cyclorama painting showed it to expand or contract about 120mm during changes in environmental conditions. After lining with fiberglass, these movements were reduced to a mere 8mm. From the positive results on thousands of paintings which have been successfully preserved in the past, and from measurements made with our instrument, we are, therefore, convinced that good lining is one of the most beneficial operations for stabilizing and preserving canvas paintings.

The authors wish to thank the Samuel H. Kress Foundation, The Joseph E. Seagram Collection, and all the other friends, too numerous to mention by name, who are helping to finance this research.

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REMOVAL OF DAMP BLOTCHES BY THE AID OF LOW PRESSURE TABLE

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SUMMARY

An example of application of low pressure table (1) for removal of damp blotches. The result of the treatment is primarily due to much air penetrating the picture, an effect obtainable on a low pressure table. This passing air carries away most of the dirt and blotches - dissolved by means of solvents - through the picture from front to back.

Case story

Inventory No. 7128
J.A. JERICHAU: Figure Composition.

Oil on cotton canvas.
131,5 x 161 centimetres.

State before treatment

No coating material has been used to prepare the picture surface for painting. The oil paint does not cover the whole picture plane. The white cotton sheeting - now yellowed, discoloured, and blotched - serves to form the ground for paint. The paint has been applied very unevenly, in some places being very thin, in others pastose. The paint has penetrated the canvas in such a way that the picture can be seen from the back. In several places oil from the paint has been absorbed in the canvas.

The picture has been exposed to water, causing damage such as large, brown blotches on the sheeting, at the bottom, and in the right corner at the top.

Due to shrinking the canvas was buckled along the edges.

Old nail holes with rust on the edges along the right, left, and bottom side.

The entire picture was very dirty.

Treatment

Loose dirt was removed from the front and back of the picture by cautious vacuum cleaning.

The picture was stretched in a temporary frame by means of paper borders, and the buckles could then be flattened on the low pressure table as follows:

A damp cloth was placed between the perforated metal sheets so that only aqueous vapour would be brought into contact with the picture.

By wiping the painting with the crumb of a fresh-baked, white bread the remainder of the surface dirt was removed from the painting under pressure.

The blotches were removed from the painting by treating it on the low pressure table as follows:

A thick piece of blotting paper (2) was placed under the picture. Both being covered with polyester foil ('Hostaphan'), suction was brought in action. The damages were partially treated by removing the foil from an area of about 2o x 2o centimetres at a time, with the effect of much air passing through specially in this area, while damages were treated with solvents in the following order:

1) 7o% ethanol
   3o% water
2) 5o% ethanol
   5o% water
3) 5o% ethanol
   5o% water
   + a few drops of Lissapol (3) (a detergent which eleminates surface tension of water and renders fats soluble. Generally used within textile and paper conservation)

- and in the following way:

The blotches were swabbed with the solvent - without touching the painted areas - and then promptly dried by means of an infrared lamp or a hair dryer. It proved most important that the drying was carried out promptly to avoid an extension of the blotches to adjoining areas. Thus blotches and dirt were removed by sucking from the back of the picture, and gathered in blotting paper, frequently changed during the process.

The treatment was repeated several times, until the blotches had almost disappeared (24 hours consumed in this case).

All parts of the painting not covered with paint were gently treated with solvent No. 3. The cotton canvas regained its light colour, and the colouristic balance redressed.

The painted areas were only cleaned with destilled water.

The provisional stretcher was removed from the picture, and to prevent the buckles from reappearing the picture was laminated on a thin Irish linen canvas ('Artist's Brown Linen Canvas', No. 3151) with Plextol D 36o.

In the main the above method is similar to what is applied to prints, drawings, and textiles. What makes this case different is the presence of painted areas, not resistant to solvents.

The very satisfactory result of the treatment is primarily due to much air penetrating the picture, an effect obtainable on a low pressure table. This passing air carries away most of the dirt and blotches - dissolved by means of solvents - through the picture from front to back.

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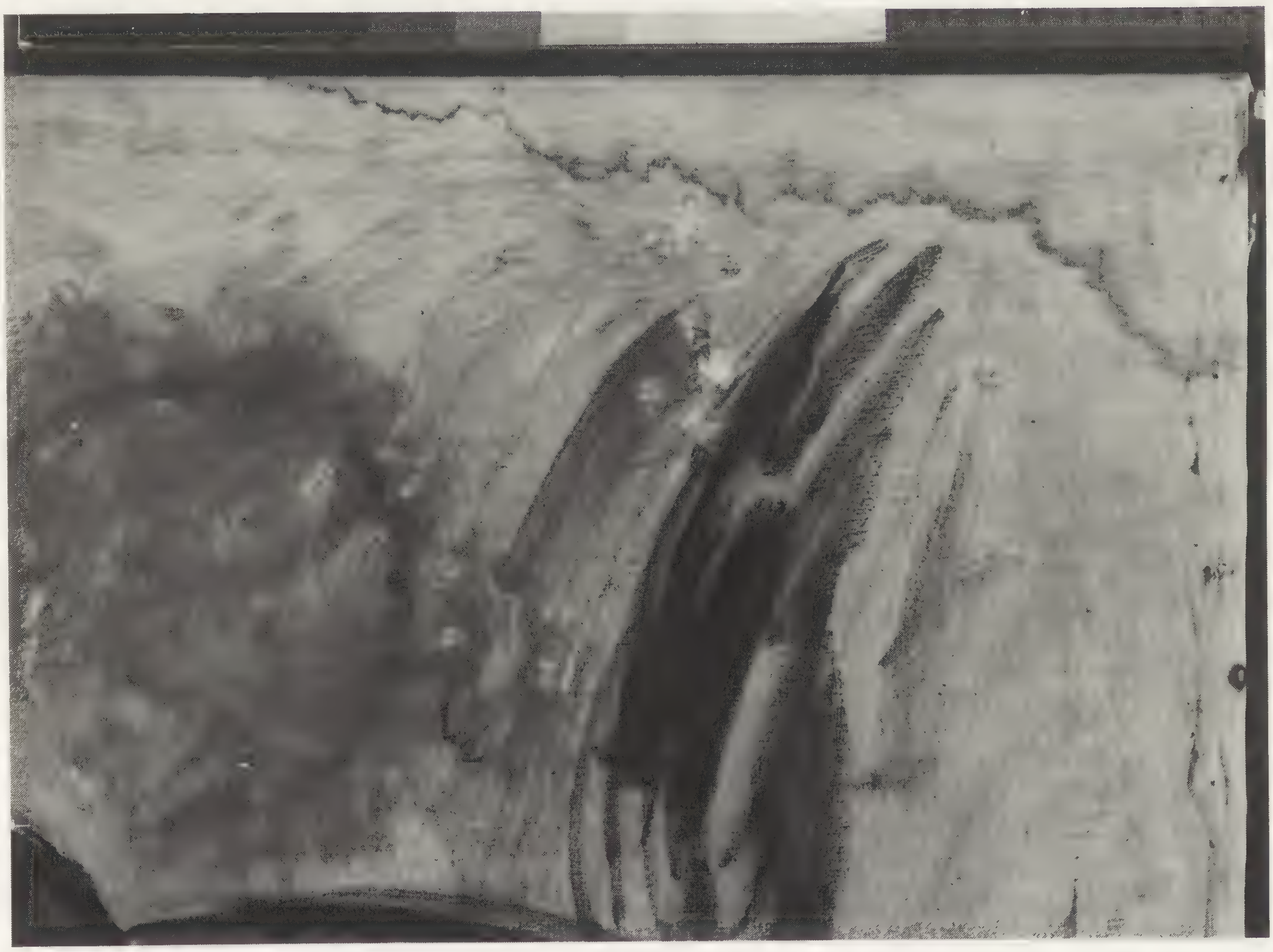
   Bjarnhof, M.: Flattening, Consolidation, and Impregnation of Paintings in The Royal Museum of Fine Arts, Copenhagen. - ICOM, 6th Triennial Meeting, Ottawa, 1981.

2) Available in rolls, 2,25 metres broad. In this case grade number 181 has been applied.

   Obtainable from: J.C. Binzer Papierfabrik KG
   Eder
   D-3559 Hatzfeld, W. Germany

3) Obtainable from: I.C.I. Danmark A/S
   Islands Brygge
   DK-23oo Copenhagen S., Denmark



Inventory No. 7128
J.A. Jerichau: Figure Composition.

Detail:
Example of damp blotches before treatment.

PRACTICAL COLD LINING DEVELOPMENTS IN SKANEATELES, NEW YORK

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SUMMARY

The process of cold lining complies to a modern preventative approach to painting conservation using minimal treatment. This relatively new process, developed in Holland by Mr. V.R. Mehra at the Central Research Laboratory, is already in use as an alternative treatment at various conservation centres in Europe.

In this paper, how cold lining has been adapted to the needs of a private conservation studio is discussed. The tools and materials are considered; the improvised cold table and how it functions, the three stretcher system, lining fabrics and adhesives.

A case history illustrates the practical techniques of the cold lining process; examination, consolidation of loose flakes, the flattening of distortion, overall consolidation of paint and ground layers and the nap bond lining. The lining is considered as a separate process and only when absolutely necessary. We must also continue to draw from a variety of treatments so that each painting receives an individual treatment designed closely to it's particular structure and problem.

INTRODUCTION

Cold lining was adopted at West Lake Conservators because the traditional methods and materials could not always solve every problem and an alternative was necessary.

The study of the "classical" materials of conservation has brought natural glues, waxes, resins and fibres under close scrutiny. (1,2) The action of excessive heat and pressure on the three dimensional character of the painting, (3,4) and the introduction of irreversible unstable materials that may alter the characteristics of the work of art (5,6) are now almost unanimously considered as being undesirable and avoidable.

The synthetic alternatives are undergoing similar critical consideration. The literature of the investigation of synthetic resins is too sweeping to mention here, but includes recent works by Robert Feller, Eddy de Witt, Garry Thompson and others. Research of adhesives (7) and fibres (8) is continuing.

Our perception of the art work has changed and paintings are now studied as three dimensional complex structures of layers, each layer with its own characteristics which cannot be considered in isolation. All components of the painting interact and influence each other and they are acted upon by external forces, such as environment and physical shock. (9,10,11,12)

This understanding of paintings is evident in recent conservation process development, proving a trend towards a minimal treatment and maximum reversibility ideal. (13,14,15,16)

Cold lining moves away from the one step lining treatment. The flattening of the paintings planar surface can be achieved by pre-stretching and moisture treatment. In the second phase, a weakened original canvas is supported with a lamination without introducing material into the reverse of the original. The lining adhesive forms a film between the original and lining canvas. Consolidation is optional and can be achieved locally or entirely as the case requires. Certain problems are resolved whenever the application of heat or adhesive absorption is undesirable.

TOOLS

The Cold Table (a)

The simple cold table is built from locally available materials, with an aluminum support frame, enclosed in wood with an arborite trim. The flat perforated aluminum table-top allows the suction of air down and away from the surface. The chamber below is tightly sealed, creating an area where low negative differential pressure forms by evacuation with a turbine blower fan, which has the capacity to maintain up to 15 cm. watercolumn pressure (ca. 6 inches watercolumn, 2/3 inch mercury) within the system.

During the lining the perforated aluminum is covered with an open celled polyurethane foam sheeting. (b) This isolates the painting from the hard metal and allows a diffusion of air under the painting. During the flattening and pre-stretching phase, the foam is replaced with a denser porous needled felt with less compressibility. (c)

The Stretchers

For smaller scaled paintings various lengths of interchangeable student line stretcher members are used. (d)

Larger strainer members over 1.5 metres long are made from construction grade lumber. The varying lengths are prepared with half-lap joints and bolt holes are drilled using a template to ensure accurate placement when the stretcher members are interchanged. (e)

The three stretcher categories are:

1. The screen through which an even application of adhesive is squeegeed in silk screen technique; the varying thickness and rate of permeability of the screen mechanically controls the amount of adhesive, thereby the amount of moisture content and cohesive force of the resulting glue film.

2. The strainer upon which the painting is held in a "dutch stretcher" during pre-stretching, moisture treatment and lining.

3. The strainer upon which the lining material is held during lining.

The Lining Materials

For the screen, three thicknesses and permeabilities were chosen from commercially available materials; the thinnest being polyester curtain material, (f) the medium, a monofilament semi-rigid polypropylene (g) and for heavy application, a polyester coated screen. (h)

To hold the painting in the "dutch stretcher", two weights are used; the lightest being spunbond polyester felt, (i) and the other, a non-woven needled felt. (j)

For the lining fabric, care is taken to replicate the weave and weight of the original canvas. The width of the material also is a limitation. The materials most commonly used are; polyester sailcloth, (k) plain weave polyester of medium weight, (l) and plain weave polyester of heavy weight. (m)

The Adhesives

Consolidants are chosen to do specific jobs, and the two types most useful are; Plexisol P550, a poly n-butyl methacrylate, (n) used in overall application or locally on thin paint and ground layers, and BEVA 371 heat seal adhesive, (o) for local consolidation of delaminating or flaking heavy paint layers.

The lining adhesive is Plextol B500, a methyl methacrylate co-polymer emulsion. (p) It can be used before or after the film has dried, depending on the painting's sensitivity to moisture. In the direct application, the adhesive is thickened with 1% Natrosol 250HHR, an hydroxyethyl cellulose, (q) and the film dries in contact with the painting. In the reactivated application, the Plextol is thickened with 15% toluene, applied to the lining canvas, let dry and sprayed with solvent (toluene or iso-propyl alcohol) before lining.

COLD LINING PROCESS

For a detailed and diagrammed description of the process, please refer to the publication by V.R. Mehra, "Cold-lining and the Care of the Paintlayer in a Triple-Stretcher System" ICOM 5th Triennial Meeting, Zagreb, 1978. 78/2/5

The case history of the cold lining of one painting is possible within the scope of this paper, an example of minimal treatment for a fairly common problem. The oil painting concerned was a larger than life scale, wedding portrait of Alice Maud Allen Atwater, (hereinafter refered to as "Alice"). The portrait was on linen canvas, 202.5 cm. high by 120 cm. wide, by Abbott H. Thayer, painted in the 1880's.

Alice was to be loaned for a travelling exhibition of Thayers' works. Proper support was therefore necessary. Upon examination, it was evident that the canvas had not been keyed out properly on the stretcher for some time, resulting in sagging of the painting due to lack of tension plus the weight of the heavy paint layers. This deformation would have to be eliminated before lining.

The ground and paint layers were sound except for locallised areas; drying cracks in some heavy paint had caused cracking through the ground, two small impact points had cracked the paint in one area and in two areas of shadow, there was active flaking of the dark glaze, otherwise, the major portion of the painting was in good condition. An overall penetrating consolidation was not necessary, only locallised treatment of the unstable areas.

In order to decide which process and which adhesives we could use, the paint, ground and canvas were tested for sensitivity to solvents, moisture and heat. Reaction to any solvent contained in any consolidant or lining adhesive would rule out that treatment. Observation of the paint's surface texture and porosity would indicate any possible change that absorbtion of consolidant would cause. Violent reaction to moisture would rule out watercontaining adhesives in lining, and moisture treatment, otherwise, as the painting is held on a dutch stretcher and under pressure on the table until fully dry, most danger is eliminated. Heat sensitivity would rule out the use of heat set adhesives being used, only cold setting. As Alice showed no apparent sensitivity to any of these factors, we decided to use BEVA 371 for local consolidation, water 1 part/diacetone alcohol 1 part for the moisture treatment and a Plexisol B500 cold lining.

Treatment of "Alice"

1. Active flaking was consolidated with BEVA. The painting was removed from the stretcher and the edges flattened.

2. The working strainers were prepared, allowing 10cm. on the inside of the "dutch stretcher" all around the painting. Upon the stretcher a non-woven polyester felt (see c) was stretched. The second working strainer fit perfectly outside the first. This second would carry the lining canvase, prestretched. Tery polyester 1666 was chosen (see m).

3. Plextol B500 was thickened with 1% Natrosol 250HHR (see p,q). The exact location of the painting's stretching edges only were masked off on a piece of screen, monofilament polypropylene (see g). The screen fit inside the first stretcher, and is the third working strainer. The Plextol was then applied to the felt, through the screen. When the screen was removed there was adhesive only where the painting's stretching edges would come in contact, leaving the reverse of the painting's canvas free of adhesive.

   The painting was then laid onto the adhesive, aligned with the stretching edges, the first strainer, with felt, adhesive and painting was put onto the cold table, the pressure turned on and the adhesive left to dry. The felt is cut away from the reverse so the the painting was held by the felt along the stretching edges on the first strainer.

4. The moisture treatment was carried out by spraying a non-warping material with 50/50 water diacetone alcohol. The material was laid under the painting and left for 30 minutes before the pressure was turned on. The painting was left under pressure until completely dry.

5. Consolidation was done locally, with BEVA along the cracks and stetching edges (this latter to ease the re-fitting of the painting later onto its new stretcher, without loss of paint from the edge.)

6. The outside dimensions of the painting was marked onto the lining canvase. Plextol, thickened, was applied to this area only, and the first strainer, with painting, was placed into the second strainer, the reverse of the painting in contact with the Plextol, the table was turned on and the painting dried under pressure.

7. A "dry-back" of tan coloured synthetic material was first attached to the new expansion bolt stretcher, then the painting, removed from the working strainer, was restretched.

8. Small losses on the edges were filled and inpainted. A matte Soluvar varnish was applied.

9. A protective backing and protective edges were attached.

CONCLUSION

Alice was returned to the Everson Museum, in Syracuse, from the travelling exhibition, without mishap. The cold lining sufficed in supporting the painting in transit. It is interesting to note here, that Thayer disliked the restoration practices of his day and perhaps can rest easy, considering his painting has been treated with such a reversible process.

We should continue to preserve paintings from further deterioration in the most natural state possible, by using materials that maintain the physical character of the painting. As these characteristics vary from painting to painting, then our treatment must be adapted to the individual requirements of each painting.

ACKNOWLEDGEMENTS

The author would like to thank Mr. V.R. Mehra for his vision of a revolutionary approach to painting conservation, along with others who have worked against convention so that we would be better prepared for treating paintings. I would also like to thank Ms. Susan Blakney-Wilson of the West Lake Conservators who has totally supported the work leading to this paper, and Ms. Margie Sutton who gave much input into the practical application, also all the members of the West Lake Studio. A special mention to Mr. John Volcko, who built the cold table and put many hours into the project.

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SUPPLIERS

a Our cold table was built to order by: Mr. John Volcko, Contech, 118 Fennell Street, Skaneateles, N.Y. 13152 USA Tel: (315) 685-5948,

b The foam is used as wick in drum humidifiers., 20 pores/sq inch Richler Custom foam 156 Solar Street, Syracuse, N.Y. 13022 Tel: (315) 475-4572,

c Needled felt AMT31150, 2 metres wide, P&S Textiles, Jordan Road, Skaneateles Falls, N.Y. 13153 Tel: (315) 685-3466,

d Available at art material shops,

e The dimensions of the members are: 2" x 4" or 5cm. x 10cm.,

f Tergal Polyester, 3 metres wide, available at interior design or draperies shops,

g various weights and porosities, from P&S Textiles, see c,

h Window screening available in hardware shops,

i Reemay 2024, known as Bontex Polyester, 1.5 metres wide, available from: Hanes Converting Co., 350 Dewitt Ave., Brooklyn N.Y. Tel: (212) 257-6565,

j Needled felt 30890, 2 metres wide, P&S Textiles, see c,

k Dacron Sailcloth, available in a wide variety of weights, from: Howe and Bainbridge, Inc., 220 Commercial Street, Boston, MA 02109, USA,

l Terytex Polyester 1666, 1 metre wide, from P&S Textiles, see c,

m Tery Polyester 39, 2 metres wide, from P&S Textiles, see c,

Suppliers Continued

n 5-10% in White spirit with 17-20% aromatic content, from Rohmtech, Inc., 10 E. 40th Street, New York, N.Y. 10016 Tel: (212) 686-6166,

o Adam Chemical Co. P.O. Box 15 Spring Valley N.Y. 10977,

p Rohmtech, Inc., see n,

q Hercules, Inc., From Road, Paramus, N.J. 07652 Tel: (201) 261-0602,

LINEN CANVAS ARTIFICIALLY AGED

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Millbank
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SW1P 4RG

Gerry Hedley

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W1H OBE

SUMMARY

The results are presented of artificial ageing of linen canvas in natural daylight, including the effects of filters and canvas treatments with antioxidants and buffers. Accelerated thermal ageing tests in air and nitrogen were also performed. The effects of prior ageing both in the light and in the dark, and the application of antioxidants, buffers and acids are discussed. Most notable of the results is that neutral and alkaline buffers were found to protect the canvas from thermal ageing.

INTRODUCTION

An understanding of the ageing process in linen canvas can enable conservators to find ways of retarding the deterioration of painting supports. The arguments for studying the ageing of linen have been given in a previous paper (1) which outlined the need to measure the rate of deterioration of linen under a variety of conditions in order to identify and assess the relative importance of each mode of deterioration. It was argued that it should also be possible to test the effects of any protective measure applied to the linen.

To achieve results in a reasonable period of time accelerated ageing tests must be conducted and to be valid these tests must be compared with samples aged naturally under known conditions. Only then would it be possible to devise conservation procedures (based on any successful treatments) taking into account the wider requirements of the works of art to be protected.

Before undertaking artificial ageing it is essential to consider what we know of the natural ageing process, that is, how linen deteriorates under museum conditions. Most conservators would agree that a certain range of environmental conditions is likely within a large public building such as a museum, and that these conditions can be improved by air-conditioning, careful control of lighting and general good management. The best conditions which can be achieved are currently thought to be:
a constant temperature of about $20^{o}C$; a relative humidity of 55 $\pm$ 5%; visible light levels below 50 lux on exposed canvas; no ultra violet light (with wavelengths less than 400 nm); concentrations of gaseous air-pollution such as SO_2, NO_2, Ozone less than 2 parts per 1000 million; the elimination of particulate matter and the removal of all contaminating material from contact with the canvas (2). Few museums would claim to fulfil all these aims and, even if they were to , deterioration may still occur. So it is important to appreciate the range of conditions which actually exist within a museum, to decide how these conditions effect works on canvas and to understand what risks ensue from any inadequacies.

The major external factors influencing the chemical deterioration of linen are probably dependant on the above environmental conditions, however, the state of the canvas, its history and condition will also affect its subsequent stability. The main components of fresh linen are cellulose (71.3%), hemi cellulose (18.5%), pectins (2.0%), lignin (2.2%), fat and wax (1.7%), water soluble material (4.4%). The presence of other materials in the canvas such as degradation products are also of great significance to the rate of ageing. In addition deterioration may be affected by: mould spores; high stresses in stretched canvas particularly at the corners and tacking edges or across paint cracks; and unavoidable contact with deleterious artist's or colourman's materials such as oil, certain pigments, iron tacks etc.

Clearly this is a much more complicated system than, for example, pure cotton fabric or rag paper, both of which have been studied extensively. (3) In order to unravel this complex state of affairs and to test some of the assumptions about the ageing of linen a series of tests have been devised.

Measurements were carried out on samples aged naturally in the Tate Gallery for 24 years under fairly accurately known conditions (4). These provided an important insight into the principal modes of deterioration and have since proved to be useful reference material for subsequent accelerated ageing tests. Light was found to be a major cause of deterioration and air pollution was strongly implicated as a serious factor. But even in the absence of these agents some deterioration occurred. Damage caused by light to cellulose is well documented (5) (6) as is air pollution (7) (8).

ACCELERATED AGEING IN NATURAL DAYLIGHT

Our first set of accelerated ageing tests (1) devised to study the effects of light involved the exposure of linen to natural daylight for the duration of one summer (July - Oct 1981). Attempts were made to eliminate air-pollution by using activated carbon filters. Two glass-fronted cabinets containing silica gel were set up on the roof of the Tate Gallery facing south and set at 45^{o} to the vertical. A relative humidity of 60-65% was maintained in one and 35-40% in the other. The light was filtered by a variety of commonly used radiation filters chosen to give a range of cut-off frequencies across the spectrum (see table 1). The canvas was of the sort used for lining paintings at the Gallery and of similar weave count and weight as that used in the 24 year old samples (Ulster Weaving Company 18 yarns/cm weft). It was washed, loomed and dried, then coated in areas of 15cm square with a selection of antioxidants and buffers which might potentially retard the ageing process in light. Table 1 shows the total number of samples and their arrangement. 34.8×10^{6} lux-hours exposure was provided (approximately equivalent to 150 lux for 10 hours a day for 70 years).

The principal method of measurement chosen to assess the extent of deterioration of the linen was tensile break load at zero length. 40 or 50 separate weft yarns were broken for each sample and the mean break load calculated. An Instron Model 1026 Tensile Tester was used to perform the measurements. A cross-head speed of 5mm/min was chosen and 25mm samples of yarn were inserted between the clamping jaw (set at zero length).

The results were treated statistically so that the mean break load, the variance and standard deviation could be calculated. The student's T test was applied to each group of samples to ensure each mean referred to a single population. The significance of the difference between two samples could then be calculated. Variances were typically about 15%. Since canvas yarns are non-uniform in cross-section and strength it is considered essential that mechanical tests should contain some statistical assessment of accuracy. Results without such an assessment should be treated with caution.

In addition pH measurements were made on extracts in cold water (0.2gm in 10ccs). The readings were all carried out consecutively using the same batch of

Table 1 TENSILE BREAK LOAD AND pH

YELLOW FILTER 101 + VA ACRYLIC					2.47 4.5				
VA PERSPEX ACRYLIC SHEET		1.77 4.1	2.18 4.4	2.23 4.5	1.98 4.3			2.1 4 4.3	2.24 6.0
VE PERSPEX ACRYLIC SHEET				2.50	2.37 4.4				
GLASS ONLY	1.99 4.2	1.28 3.8	1.98 4.3	1.98 4.3	1.86 4.2	2.01 4.1	1.18 3.8	1.84 4.2	1.99 5.9
ORDINARY GRADE PERSPEX				1.92 4.3	1.56 4.2			1.79 4.1	2.00
DARK				3.07 5.2	3.03 4.9				3.03 6.9
WEFT	POTASSIUM HYDROGEN PHTHALATE	1% 1010 3% PS800	2% 1010	1% 1010 IRGANOX	UNTREATED CONTROL	TOPANOL CA 1%	TOPANOL CA 1% PS800 3%	IRGANOX 565 1%	MAGNESIUM BICARBONATE SOLUTION

deionised water on an E.I.L. pH meter.

Reflectance measurements were not performed but the canvas was photographed after ageing (fig 1).

RESULTS

Relative Humidity

By comparing the strengths of yarns taken from both boxes it was possible to say that there was no significant difference between yarns aged at 35-40% RH and those aged at 60-65% RH. Unfiltered and untreated canvas was used for this comparison. Although there is some evidence to suggest that light ageing of cellulose is humidity dependant (5) this does not appear to be an important factor in the relative humidity range found in most museums.

The effect of wavelength

The cut-off frequency for each filter is given in table 2 which shows the variation of strength against cut-off frequency. As would be expected the strength decreases with shorter wavelengths (9) U-V radiation is much more damaging than visible light. Significantly blue light is also very damaging, and the difference between the two filtered acrylics (V.A. and V.E. Perspex) suggests that it may be worthwhile removing the small amount of blue light on the edge of the visible spectrum. This could be done by filtering the light source rather than by covering the object so that the resulting colour temperature change would not be noticed.

It is clear from the tensile break loads that these differences are statistically significant and provide reliable evidence for devising a conservation procedure.

One problem emerged from this set of results. The canvas from the unfiltered control proved to be stronger than that behind ordinary grade Perspex. Reexamining the conditions in the ageing cabinet by measuring the temperature above the samples revealed, in direct sunlight, a temperature of 60°C above the sample covered by perspex and 56½°C above the unfiltered control. The extra heating associated with the perspex cover is probably caused by the downward reflection of any longer wavelength radiation emitted by the surface of the canvas (the greenhouse effect). The observed difference in tensile strength may therefore be explained by extra thermal ageing of the linen.

The chart shows a good correlation between tensile break load and pH for ageing under these conditions. Acidity increases as the canvas deteriorates.

Thermal ageing effects

It is worth noting that there is no observable decrease in strength for the samples kept in the dark although they must have been subjected to some thermal ageing. An approximate calculation based on the Arrhenius equation and assuming linear deterioration (which is unlikely) suggests a 5% loss of strength could be attributed to thermal ageing (10) (11). Further investigation of this thermal effect is carried out in the second of our tests.

Table 2

FILTER	BREAK LOAD	pH
DARK 700 nm	3.03	4.9
YELLOW 460 nm	2.47	4.5
V.E. ACRYLIC 400 nm	2.37	4.4
V.A. ACRYLIC 385 nm	1.98	4.3
O ACRYLIC 305 nm	1.56	4.2
GLASS ONLY 305 nm	1.86	4.2

Table 3

	BREAK LOAD KG
CONTROL UNTREATED	1.86
1% IRGANOX 1010	1.98
1% TOPANOL CA	2.01
1% IRGANOX 565	1.84
2% IRGANOX 1010	1.98
1% IRGANOX 1010 3% IRGANOX PS800	1.28
1% TOPANOL CA 3% IRGANOX PS800	1.18
MAGNESIUM BICARBONATE BUFFER pH 7-8	1.99
POTASSIUM HYDROGEN PHTHALATE pH 4	1.99

Antioxidant Treatment

The effects of the various applications of antioxidants and buffers can also be seen in the table. The primary antioxidants Topanol CA and Irganox 1010 afforded some small protection, Irganox 565 provided no protection. Both the applications involving PS800 secondary antioxidant showed signs of increased deterioration and acidity. It is possible that the protection provided by Topanol CA and Irganox 1010 could be explained simply by their light filtering or reflecting properties. Antioxidants (12) are known to protect materials by removing free radicals or excited molecules, (primary stabilizers) or by reacting with peroxyradicals (secondary stabilizers). From our results it appears that either the antioxidants are consumed quite quickly by this process or that the activated groups react with the cellulose in preference to the antioxidants. In any event antioxidants are normally intended for use in solution where they would be in intimate contact with the material to be protected. Using antioxidants as coatings may have reduced or eliminated their effectiveness.

Treatment with buffers

The buffers investigated were Magnesium bicarbonate, a neutral buffer and potassium hydrogen phthalate solution, a weak acid of pH4. Neutral buffers could in theory protect the canvas from acid hydrolysis.

The mechanism of hydrolysis is thought to depend on the presence of free hydrogen ions H+ which can cause the breaking of the glycoside link in the cellulose molecule. This leads to a decrease in the chain length of the polymer and is observed as a fall in strength of the yarns. The rate of hydrolysis depends on the number of hydrogen ions (measured by pH). Carboxylic acids produced by the oxidation of cellulose can provide these ions (as could any other acids, for instance the external pollutants sulphur dioxide or nitrogen dioxide).

The pH of the untreated sample fell to 4.2 following

Fig. 1

Linen canvas after ageing in natural daylight. For key see fig. 1. The bottom row received no light. The top row was covered by a yellow filter. All the other rows were exposed to blue and/or U.V. light.

light ageing whereas the Magnesium bicarbonate, treated sample remained at 6.9 in the dark and 5.9 in the light. However the tensile break load showed that only a small protection was afforded by the buffer. The sample buffered to pH 4.2 with potassium hydrogen phthalate might have been expected to show increased deterioration. However there was no evidence for this, which may indicate that acid hydrolysis is not a major mechanism for the deterioration of linen in strong light and above pH 4.2.

The photograph shows that bleaching is the dominant colour change on exposure to light.

DISCUSSION

It is important to consider these empirical results in the context of other results and theories concerning the ageing of cellulose in light. (6) The process most likely to occur in museum conditions is probably photosensitization (14). Light falling on non-cellulosic materials such as lignin, pigment, size, pectin etc causes the excitation of their molecules. The excited molecules react with either cellulose or water to produce free radicals. In the presence of oxygen, cellulose free radicals produce peroxy radicals. Further reactions produce carbonyl and carboxyl groups opening up the pyranose ring in the cellulose molecule. Since the yellow colour in degraded cellulose is attributed to carbonyl groups, (15) it seems probable that in strong light where bleaching has occurred the carbonyl groups will all have been oxidised to carboxyl groups. This would explain the increased acidity generated on light ageing.

The photosensitization mechanism does not require that any hydrolysis reactions occur so the failure of buffers to protect the canvas should not be surprising. However the production of carboxylic acid groups by the light ageing would indicate that there would subsequently be an increased rate of deterioration caused by acid hydrolysis. Following exposure to strong light canvas kept in the dark would deteriorate at a faster rate than would otherwise occur in the dark. The phenomenon is known to occur in pure cellulose (2) and is investigated in our second accelerated ageing test.

THERMAL AGEING

Samples of washed canvas were prepared as before and cut into 25 x 40mm rectangles. These samples were tied like flags onto glass rods and placed in 3 glass flasks in such a way that they were not touching each other or the sides of the flask. Activated carbon (in polyester bags) was placed in the flasks to absorb any pollution and volatile degradation products. Filter papers were soaked in cobalt chloride to enable a constant humidity to be maintained. The flasks were sealed and placed in an oven. The temperature was raised to 85°C and deionised water was added to maintain the pink colour of the cobalt chloride. 2 further flasks were prepared in the same way except that a slight positive pressure of oxygen-free nitrogen was applied (following flushing with nitrogen). In this way all the samples were aged in the dark for 55 days.

In another test further untreated samples were aged at 60°C for 10, 20, 30, 40, 50, 60 days.

Table 4
The effect of thermal ageing on linen canvas.

Linen canvas - thermal ageing at 85°C for 55 days in air - Tensile break load g.		
Canvas freshly prepared in 1983. Initial strength 3030	Canvas previously thermally aged. Initial strength 3030	Canvas previously aged in daylight. Initial strength 1860
Untreated control 1624	Untreated control 474	Untreated control 234
Untreated canvas enclosure - outer 1699	Irganox 1010 685	Irganox 1010 228
Untreated canvas enclosed - outer 1734	Topanol CA 499	
Untreated canvas enclosed - inner 1798	Klucel G. 349	
	Potassium hydrogen phthalate pH4 1074	Potassium hydrogen phthalate pH4 245
Calcium hydroxide 2712	Magnesium bicarbonate 2560	Magnesium bicarbonate 1143
	Methyl magnesium carbonate 2876	

The tensile break load at zero length and pH were measured as before. Also the reflectance coordinates were measured and the samples photographed.

Three types of samples were chosen (see tables 4 and 5).

1) Freshly washed, new canvas (1983)

2) Canvas from the previous test which had been aged in the light for 34.8 x 10^6 lux hours (behind glass but in otherwise unfiltered daylight).

3) Canvas, also from the previous test, which had been kept in the ageing cabinet in the dark (as a control). This canvas would be expected to have suffered some thermal ageing.

RESULTS

Tables 4 and 5 show the range of samples tested and the tensile break load measurements made so far. The rest of the results will be given in the lecture.

Table 5

Linen canvas - thermal ageing at 85°C for 55 days in nitrogen - Tensile break load g.		
Canvas freshly prepared in 1983. Initial strength 3030	Canvas previously thermally aged. Initial strength 3030	Canvas previously aged in daylight Initial strength 1860
Untreated control	Untreated control 1479	Untreated control 684
	Irganox 1010 1627	Irganox 1010 737
	Topanol CA 1761	
	Klucel G.	
	Potassium hydrogen phthalate pH4 1920	Potassium hydrogen phthalate pH4
Calcium hydroxide	Magnesium bicarbonate 1967	Magnesium bicarbonate
	Methyl magnesium carbonate	

The effect of prior ageing

The freshly prepared untreated canvas has retained 54% of its strength on thermal ageing in air. The previously light aged untreated canvas has retained only 12.6% of its strength. The control previously thermally aged in the dark has retained only 15.6% of its strength.

Clearly thermal ageing is more rapid when the canvas has had prior exposure to light. As was suggested earlier this could be because the light exposure has oxidised the linen, increasing its susceptibility to acid hydrolysis (16).

Thermal ageing is also quite rapid when the canvas has undergone prior thermal ageing even though this previous ageing was considered to be small. In the previous test the samples aged in the dark lost little or none of their strength and the thermal ageing was estimated to be only about 5% of that caused by light. It therefore seems likely that an activation process had occurred which was not reflected in the tensile break load measurements. It may also mean that the rate of deterioration increases as the canvas ages (17). Results from the ageing tests at 60°C should help to establish these effects.

Ageing in nitrogen

The previously light aged canvas has retained 37% of its strength when thermally aged in nitrogen. The previously thermally aged canvas has retained 49% of its strength, under nitrogen. In both cases the linen has survived better than in the corresponding ageing in air. Since in nitrogen internal acidity cannot be generated by oxidation it is reasonable to assume that the deterioration is likely to be caused by hydrolysis.

The extent of the hydrolysis will be dependant on the initial acidity (pH 4.2 and pH 4.9) of the linen. The results also suggest that hydrolysis is the dominant, but not the only, effect of thermal ageing in air.

Antioxidants

The sample previously treated with Irganox 1010 and light aged was not significantly protected during thermal ageing in air. However some small protection may have occurred in the sample previously aged in the dark. A similar but even less clear-cut effect can be observed for the samples aged in nitrogen.

The sample previously treated with Topanol CA and thermally aged showed no protection on subsequent thermal ageing in air but some small protection in nitrogen.

The significance of these small effects is not clear and would require further investigation though they are of little immediate interest to the conservator.

Enclosure

Enclosing the canvas between two canvases (table 4) provided no significant protection for fresh canvas thermally aged in air. This suggests that in our test a rapid circulation of air is not necessary (2) for degradation to occur. However conservators' experience of naturally aged canvases is that loose linings, blind stretchers, backboards and stretcher members do appear to reduce the deterioration of the original canvas. Therefore this discrepancy must be explained by the presence of other factors in the real environment. Our studies suggest that acidic pollutants or the occasional tendering of the canvas by exposure to light could be important.

Treatment with buffers

The results of the buffer treatment are of considerable significance for the control of canvas deterioration. The sample previously treated with magnesium bicarbonate and light aged retained 57% of its strength following thermal ageing in air. The sample previously aged in the dark retained 84% of its strength. Both are considerably better than the untreated controls.

Following thermal ageing in nitrogen the sample, previously treated with magnesium bicarbonate and light aged, retained 65.5% of its strength.

The magnesium bicarbonate treatment shows a dramatic protection of the canvas in air and would seem to be retarding the hydrolysis of the cellulose.

Freshly prepared canvas treated with $Ca(OH)_2$ retained 90% of its strength when aged in air. Methyl magnesium carbonate freshly applied to a canvas previously aged in the dark retained 95% of its strength, after thermal ageing in air.

Taken together these results suggest a highly significant protection afforded by neutral buffers for canvases previously light aged, aged in the dark and freshly prepared, (18), (19), (20).

The samples treated with potassium hydrogen phthalate, a pH4 buffer, are also of interest. For thermal ageing in air the previously light aged sample showed no protection, the sample aged in the dark appeared to be significantly protected although not nearly as well as by the neutral buffers. Very good protection was also provided for the sample previously aged in the dark and then thermally aged in nitrogen. This suggests that the pH4 buffer can prevent the formation of greater acidity which would otherwise occur. The pH measurements following thermal ageing may help explain this protection. These will be given in the lecture.

Acid Treated

The samples freshly prepared and deliberately acidified (see figure 2) were not tested for tensile break load since they had all become extremely weak. However colour measurements indicated a discolouration dependant on the initial acidity. It does not appear to depend on the choice of acid.

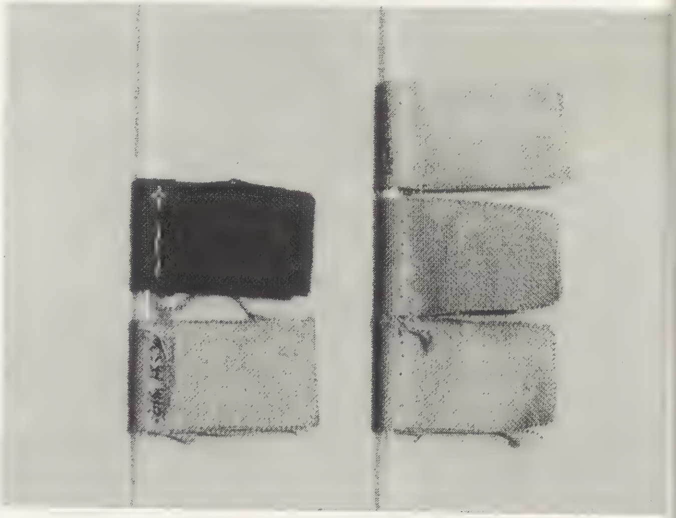

Fig 2. acid treated canvas after ageing left: 0.1M H_2SO_4; 0.01M H_2SO_4. Right: control; 0.05M Hcl; 0.001M H_2SO_4.

CONCLUSIONS

Accelerated ageing tests, as discussed above, have attempted to encourage (preferentially) particular degradation modes in order to gain information about their relative significance. Although the results must be interpreted with caution (21) (22), they do allow us to analyse the behaviour of linen canvas under a variety of conditions relevant to those found in a museum. In the absence of external pollution the rate of deterioration of linen canvas proceeds slowly in the dark. Exposure to light dramatically accelerates the ageing of canvas. Canvas which has had prior exposure to light or undergone some thermal ageing subsequently deteriorates more rapidly in the dark than would otherwise have occurred. A possibility of an inductive process occurring in the dark has been noticed.

Filtering natural daylight to eliminate U.V. radiation and some of the blue light can help to reduce light damage (photodegradation). This light damage is not dependant on relative humidity in the normal museum range. Buffers and antioxidants have only a marginal effect on the degradation caused by light.

Canvas ages more rapidly in air than in nitrogen. The rate of deterioration in the dark depends on the initial condition of the canvas. The application of neutral buffers significantly slows the rate of deterioration of canvas irrespective of whether it be fresh, previously light aged or previously thermally aged. Treatments based on the application of these buffers can in principal be recommended particularly for canvases which have become acidic. It is now necessary to investigate the effects of such buffers on canvas colour and dressings, as well as to consider methods of application.

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LINING IN 1984: QUESTIONNAIRE REPLIES

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SUMMARY

A detailed account of 93 replies to a questionnaire on lining is given. These are compared with the replies to an earlier questionnaire reported to the Venice I.C.O.M. meeting in 1975. Significant among the findings are the large variety of lining methods and materials employed; the widespread adoption of BEVA 371; the dramatic fall in average pressures used during vacuum lining; the increasing interest in and use of Air Flow tables and the developments in the use of moisture to correct paint, ground and canvas deformations.

INTRODUCTION

Nine years have elapsed since the practices and materials of lining were surveyed and reported to the Venice I.C.O.M. meeting in 1975.(1). It was felt that during this time important shifts in methods and approaches were likely to have occurred, and that consequently a new survey would more accurately reflect current practices. This paper summarizes the replies received from a questionnaire circulated in late 1983.

Around 250 questionnaires were sent, mostly to conservators listed in the I.I.C. members booklet. 93 replies were received; this represents a response of one reply for every 2.7 questionnaires. This is a fairly good response rate, the previous questionnaire received a total of 52 replies. The good response reflects in part the relatively few and short questions, but also the continuing concern with lining.

39 replies were received from North America (35 USA, 4 Canada) and 44 from Europe. There were 6 responses from Australasia, 3 from Latin America and one from India. As will be seen, the size and relative balance between North American and European replies has enabled some differences in approach between the two regions to be broadly identified. The replies from Europe comprised United Kingdom 19, Switzerland 6, Germany 4, Denmark 4, Sweden 2, Holland 2, Austra 2, with one reply each from Belgium, Czechoslovakia, Norway, France and Italy.

At the outset it ought to be emphasised that the total sample cannot purport to represent the whole of conservation practice. It should be more accurately thought of as reflecting the methods of those conservators who attend or relate to the international meetings of the profession. In addition the use of English only in the questionnaire may have contributed to the poor response from some European countries, e.g. Italy, France.

Taking both of these factors into account it is evident that the practice of animal glue/flour paste lining is the process most under-represented in the replies. Allowance ought to be made for this when assessing total present practice.

The sample is, however, very close in composition to that of the 1975 questionnaire and ought therefore to reflect changes in practice amongst this grouping.

The responses to each question are outlined and discussed below. Not all answers total 93 since some questions were occasionally left unanswered or allowed for more than one option.

1. LINING ADHESIVES. The choice of lining adhesives is shown in Table 1

Adhesive	Mostly	Regularly	Rarely	Not used
Wax or Wax/Resin	21	25	38	9
BEVA 371	14	40	25	14
Dispersions	6	15	28	44
Animal Glue/ Starch paste	2	10	31	50
PVA Resin Formulations	0	10	41	41
Fabri-Sil	1	5	21	65
Other	1	4	11	75

Table 1. Choice of Adhesives

Wax formulations and BEVA 371 are the two most widely used adhesives. Indeed, although more use wax adhesives 'mostly' (21) than BEVA 371 (14), when the numbers of those who use an adhesive 'regularly' and 'mostly' are summed it would seem that BEVA 371 (54) is probably more widely employed than wax (46). The same summation for the other adhesives gives Dispersions (21), Glue/Paste (12), PVA Resins (10), Fabri-Sil (6).

These figures represent an important change since 1975. Then wax was the overwhelmingly dominant adhesive (43 out of 52 used it regularly) and hardly any, 2, used synthetic adhesives regularly, though 34 had experimented with some type of synthetic. Wax is still widely used, indeed, only 9 do not employ it at all, but it is also striking that only 14 do not employ BEVA 371. All the other adhesives are not used by around 50% of the sample.

A second important trend that emerges is the tendency of conservators to employ a wide range of adhesives to meet different problems. 43 of the sample used 4 or more different adhesives, 34 used three adhesives and only 15 used two or less. This reflects a much more flexible approach and also emphasises the broadening of the field of lining and of the practical skills required.

This tendency to use a lot of adhesives was more evident still in North America where 28 of 39 used four or more (up to 7).

Many different wax/resin formulations were given. They divided roughly equally between those based on beeswax (23) and those based on micro crystalline waxes (21) with some using both together (8). Micro crystalline waxes were far more popular in North America: 17 of the 21 came from there and 6 of the 8 beeswax/micro crystalline mixtures were also from North America.

12 used adhesives based solely on wax with no resin addition; 11 of these were micro crystalline waxes and the other mixed beeswax and micro crystalline wax. 11 of these 12 wax only users were North American.

A broad range of resins and proportions was employed so that no general conclusions can be made except that wax adhesive formulation still appears to be rather haphazard and personal. Beeswax/Dammar mixtures in the region of 60%/40% continue to be popular outside North America.

The lack of popularity within the sample of natural glue/paste practices was further emphasised by the formulations given. Of 9 recipes 4 specified using 100% starch only and one used pure sturgeon's glue.

No fewer than 13 different polymer dispersions were listed as being used; it was not always clear from the answers whether they were used with or without heat.

Nearly all, 23 of the 27, users of Fabri-Sil were North Americans; this may well reflect problems of availability and cost outside the region.

2. LINING TECHNIQUES

Lining Techniques employed are shown in Table 2.

	Mostly	Regularly	Rarely	Not used
Vacuum Hot Table	20	36	19	18
Hand lining	14	17	37	25
Air Flow systems	8	18	13	54
Other	3	5	2	83

The continued wide usage of vacuum hot tables is clear; in 1975 80% of the sample used them; in this survey the percentage is almost identical (80.6%).

Amalgamating the 'mostly' and 'regularly' responses gave Vacuum hot tables 56, Hand lining 31, Air Flow 26 and others 8. Hand lining has changed little in popularity between the two surveys. The major change has been the introduction of Air Flow tables with 39 recorded users representing 42% of the sample. 22 of the tables could be heated.

Techniques listed under "other" included the Electrostatic Table and the so-called "drop linings" or flocked BEVA 371 processes. A number of people noted using the hot table solely as a heat source and not employing the vacuum pressure capacity.

Again conservators tend to employ a wider range of methods; 58 use 3 or more techniques with 35 using 2 or less. In North America, this is more pronounced with 29 out of 39 (74%) using 3 or more methods.

It is in the area of vacuum pressures that the biggest changes in practice have occurred. Incredible as it may seem now, in 1975 the average vacuum pressure used was about 20"Hg (500m Hg); the distribution of pressures shown below from this survey indicates the much lower pressures used today.

PRESSURE INCHES Hg

	"A MINIMUM"	0 - 1	1 - 2	2 - 5	5 - 10	10 +
Number	14	20	11	12	8	8

Although it is hard to interpret answers such as "as little as possible", if it is assumed that they fall below 2"Hg, then 45 of the 73 pressures given were less than 2"Hg. This is more than half the sample. Evidently this reflects the much greater awareness of surface texture change in vacuum lining which emerged in the early '60s and was an important concern at the Greenwich lining conference in 1974. North Americans tend to use lower pressures than others.

This concern with surface texture is also clear in the widespread use of envelope techniques. Only 25 respondents never use envelope methods and 43 recorded using them mostly (18) or regularly (25).

This greater sensitivity to the surface of paintings reflected in lower pressures, envelopes, drop linings, Air Flow tables, etc., would seem to be the most important change as far as the techniques of lining are concerned.

3. LINING FABRICS

Nearly all, 79, use linen as a lining fabric; only 14 do not. 54 specified using glass fabrics and 33 used polyester fabrics. 17 of the polyester fabric users mentioned using sail cloths. The question did not ask for information as to frequency of use of each fabric.

In the 1975 survey all respondents used linen; 34% used glass fabrics and only 6% other synthetics. The main differences are thus in the increased usage of glass fabrics, up from 34% to 58%, and of polyesters which are now employed by 36% of the sample.

A number of other lining fabrics were mentioned. These included hemp, cotton duck, polycottons, polypropylene, polyvinyl alcohol (Tencate), Fabri-Sil and nylon.

4. DO YOU USE INTERLININGS? IF SO, WHAT DO YOU GENERALLY USE?

57 respondents said they used interlinings; of these 28 were North Americans, indicating the rather greater popularity of interlinings in the USA and Canada (71% as against 54% elsewhere). 18 of the total 57 who use interlinings stated that they did so only rarely, 4 of the 28 North American users said they did it rarely.

More than 20 different interlining materials were listed. Popular choices include glass fabrics, paper/tissues, non-woven felted synthetics, (e.g. Pellon/Vilene), nylon gossamer and natural fabrics.

5. DO YOU EMPLOY PRE-STRETCHING TREATMENTS?

76 replies noted using some type of pre-stretching of the painting. 10 of these said that they did it only rarely and 10 others said they definitely did not pre-stretch. The question did not enable a clear distinction to be made between those who pre-stretch to expand a painting in order to treat surface problems like tenting and those who pre-stretch merely as a handling convenience or else to provide resistance against shrinkage during treatment. It does seem, however, that pre-stretching has increased significantly because only just over a quarter (27%) of those questioned in 1975 stretched paintings prior to lining.

As to the methods used, 9 mentioned using the "Dutch" method, 2 the "Greenwich" method and 2 the Rigamonti system.

6. DO YOU USE MOISTURE AND/OR SOLVENT TREATMENTS TO ASSIST WITH THE CORRECTION OF DEFORMATIONS? IN WHAT WAY?

Only 3 conservators replied "No", they never used moisture or solvents; 30 indicated that they used both on occasions and over half, 47, said that they only used moisture.

Of the methods that were described the most popular was the use of moistened paper or misting the reverse of the painting, either locally or over all, in combination with weights or low pressure on the vacuum hot table. Air Flow tables are also being used in the correction of deformations of both paint/ground layers and the fabric support.

A very interesting development in North America is the use of high humidity chambers reported by 11 conservators there. The R.H. employed within the chamber ranges from 75-90%. One conservator reported using salt solutions to maintain the RH and a fan to assist air circulation. The painting is maintained in this environment for a prolonged period (days). 2 conservators indicated that the painting was held with the tacking margins exposed on a working stretcher during this time, and while the RH was gradually reduced the painting was kept under weights and blotters.

Among the solvents used in various combinations with water are ethanol, IMS, diacetone alcohol, cellosolve and ethylglycol. 3 North American conservators routinely follow solvent treatment with wax impregnation; 2 mentioned adding cellosolve to wax to com-

plete solvent treatment and infusion simultaneously. 4 conservators mentioned using the technique described by Margaret Watherston at the IIC Lisbon Conference in 1972.

This question was not posed in 1975 and reflects the current generally consistent practice of treating separate problems separately rather than relying on lining as a panacea. In 1975, 25 of the 52 conservators who replied to the questionnaire mentioned that they treated flaking prior to lining. Flattening prior to lining is not new, but the correction of deformations is beginning to be achieved by different methods and in some cases it results in avoiding lining altogether. In general it would appear that conservators are now more ready to employ moisture based treatments and that organic solvent treatments are attracting interest.

7. DO YOU EVER MOUNT PAINTINGS ON SOLID SUPPORTS? IF SO, WHAT DO YOU USUALLY USE?

60 conservators replied "yes" and of these 19 indicated that they used solid supports only "rarely" or "very rarely" and generally only for very badly torn paintings. 31 conservators stated that they never used solid supports at all.

A strikingly wide range of materials and combinations of different materials are being used. By far the most popular are honeycomb constructions: either aluminium or paper honeycomb cores with aluminium, resinated fibreglass or masonite skins. Sundeala and Millboard skins are also used. Our impression is that aluminium honeycomb with aluminium skins is currently the most common choice.

These constructions may be bought ready-made (e.g. Aerolam, Alucobond) or, as some conservators indicated, designed and made in the studio. Among the self-assembled supports described are aluminium skins with a polystyrene core; aluminium skins with end grain balsa wood core; birchwood skins with end grain balsa wood core; resinated (polyester or epoxy) fibre glass with an aluminium honeycomb core; resinated paper with an aluminium honeycomb core; conservation board or masonite with a paper honeycomb core; perforated Plexiglass with a porous sintered polyethelene core. Sheets of aluminium, perspex and masonite are also sometimes used alone. One conservator mentioned polycarbonate sheet and 3 mentioned hardboard.

A few conservators indicated a clear preference for a multi layer lining or a semi rigid rather than solid support, such as polyester infused fibre glass or a heavy mylar laminate.

The difficulties of removing solid supports were a general cause for concern.

8. HAVE YOU USED MODIFIED STRETCHERS, E.G., SPRING STRETCHERS? IF SO, PLEASE SPECIFY THE TYPE

47 conservators have used modified stretchers at some time including their use as working stretchers only; 43 conservators have never used them.

A wider range of modified stretchers is available in America and the replies reflected this: only 7 of those who had never used modified stretchers were North American, while 32 (out of 47) users were North American. This trend towards the employment of a broad range of methods for stretching paintings coincides with our findings for lining procedures in North America.

The most popular modified stretchers are the expansion bolt (Lebron frequently specified) or turnbuckle type. 24 conservators specify this type and some are producing their own designs along these lines. 14 conservators specify I.C.A. spring stretchers although 3 mentioned problems or had ceased to use them and one replaced the springs with metal tubing "to eliminate the property of constant tension and the possibility of constant expansion if the corner binds"; 6 specified Lascaux stretchers; 4 specified Rigamonti stretchers although one had stopped using them; 2 specified constant tension stretchers developed by Berger and Russell. 4 conservators also expressed a definite preference for preserving and reconditioning the original stretcher if at all possible. One conservator uses fixed stretchers with no keys following a seventeenth century design.

The development and interest in modified stretchers is relatively recent and the nature of the replies while indicating an active interest also made it clear that they were not being used on a regular basis yet. There appears to be a clear division between those favouring expansion bolt and those favouring the spring systems. The latter seems to be more problematic.

9. HOW FREQUENTLY DO YOU STRIP LINE PAINTINGS?

82 conservators do strip line paintings, but of these half (40) indicated that they did so rarely or very rarely. 27 said that they did it often. In most cases the reply can be summarised as "it depends on the particular painting".

We did detect a greater aversion towards strip lining among North American conservators than others; of the 7 conservators who replied "No", 6 were North American and half (20) of those who strip lined rarely were North American.

10. HAVE YOU EVER DE-LINED A PAINTING AND NOT SUBSEQUENTLY RE-LINED IT?

28 conservators answered "yes", although some indicated that they had only delined a painting without subsequently relining it once. 2 conservators said that they did it often. Of those who answered "no" 4 said that nevertheless they had considered it.

2 conservators described reversing wax linings and one had replaced the lining with a loose-lining. One described reversing a lead white lining adhesive and replacing it with a mylar barrier. Strip lining was also mentioned as an alternative.

This question and the previous one were not posed in 1975. However, we felt that the replies indicated a shift in attitudes or rethinking of these issues.

11. DO YOU THINK YOU LINE PAINTINGS LESS OFTEN AS A ROUTINE PROCEDURE THAN YOU USED TO?

62 conservators, two thirds of the respondents, replied "yes", they did line paintings less often as a routine procedure. 11 conservators gave a definite "no", but some of these indicated that they were young or that their attitude had been formed during the last ten years. One conservator lined paintings more often. 13 conservators simply replied by saying that with them lining was "never a routine procedure" and 3 of the "yes" answers also indicated this.

12. HAS YOUR ATTITUDE TO LINING ALTERED DURING THE LAST 10 YEARS?

73 conservators replied "yes" and only 11 (out of 93) gave a definite "no". Of these "nos" 3 indicated that they still preferred wax lining and one hand lining to all other methods.

The most significant general conclusion to be drawn from the comments that accompanied the replies is that attitudes have changed and are changing and that as a consequence the majority of conservators now actively try to avoid lining for as long as possible. Strip lining, loose lining, stretching around a solid support, protective framing and enclosed cases are some of the alternatives adopted. When lining becomes an inevitability consideration of the variety of materials and methods available allows for greater flexibility of approach than in the past.

Aesthetic Standards

Many conservators commented on what they felt was a greater sensitivity towards the surface texture of a

painting; heightened awareness of the various texture changes brought about by lining and their general willingness to accept minor surface irregularities "that would in the past have been viewed as blemishes that might have justified intervention in the form of lining". Another comment is typical: "as a student I was taught to wax line everything as an only solution to problems. Today, however, I am willing to accept slight deformations as an integral part of the piece or use different materials ..." The widespread use of interlinings, particularly in North America and much more significantly the radical drop in vacuum pressures used during lining (see question 2) are to be seen as aspects of the attempt to minimise texture change during lining. One of the far reaching consequences of this awareness is the treatment of serious planar distortions prior to lining (see: prestetching and moisture/solvent treatments, questions 5 and 6) in order either to avoid lining altogether or "avoid relying on extreme vacuum pressure during lining ... and risk a general flattening of the painting surface". The majority of our replies came from institutions, but one private conservator noted that "he had managed to persuade clients that they do not need to have flat paintings".

Non-Intervention

Many respondents characterised themselves as having become "minimalists" or "non-interventionists" and "tending to work towards types of lining where as little treatment as possible is carried out". Lining is described as a "last resort" and lining as either a preventative measure or as a comprehensive conservation treatment received no general support at all.

It is clear that many institutions are concerned by the problems posed to paintings by travelling to exhibitions and the effect that this has on their conservation policy: "If museums continue to wish to transport paintings all over the globe there will be more need for lining rather than less. This is our problem". Some stated categorically the principle: "We never line just so a painting can travel", while others mentioned that they had had to do just that. Unstable environmental and storage conditions, whether public or private, posed difficulties especially for private conservators, area museum services and smaller museums and in such circumstances the principle that "a lined painting generally sustains less damage from a hazardous environment than an unlined one" is still given currency. Environmental factors affected different conservators differently. One conservator from South America stated "we have adopted wax lining because of the high humidity conditions of our climate", while another in India is prompted by a tropical climate to search for a suitable pressure sensitive formulation.

Most conservators' concept of lining today can be summarized by the statement "we see lining as functioning as a support for the original and not as a solution for any other problems". "An impregnating lining used to be regarded as a comprehensive conservation treatment; during the last 10-15 years this attitude has become less acceptable as the problems of removing distortions, consolidating flaking films, preserving canvas and reinformcing already degraded supports have come to be seen as requiring different but interrelated solutions". Even the convinced wax resin liners emphasised that it was not a "panacea".

Range of Materials

The fact that the present range of available lining materials and methods has inevitably affected attitudes and in particular allowed for the development of greater flexibility and sensitivity of approach is noted by many conservators. "Adhesives and lining fabrics are selected to suit the particular needs of each individual object". It is easier "to match the needs of the painting with the most appropriate treatment". This is reflected in the responses to questions 1 and 2: 43 conservators use 4 or more adhesives and 58 use 3 or more lining techniques. However, the range of materials also caused concern for long term stability, as compared with tried and tested adhesives such as wax and long term efficiency as compared with the elimination of surface deformations by glue-paste linings. More crucially perhaps one conservator made the following observation: "a problem with using a variety of methods is that each one has its own craft. Is it better to use a good method badly or a poor method expertly?"

ACKNOWLEDGEMENT

We should like to thank all those who took the time and trouble to answer the questionnaire and therefore made this survey possible.

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ENZYMATIC REMOVAL OF LINING PASTE FROM PAINTINGS

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SUMMARY

The paste used for the lining of paintings is absorbed by the canvas, by the ground and often also by the surface of the paint layer. It cannot be removed completely by scraping only, but it is possible to remove most of it by means of an enzymatic reaction. The paste consisted of meal, glue and resin. Mould (Penicillium sp. and Aspergillus fumigatus), bacteria and yeasts taken from the paste were inoculated on a Sabouraud agar with lining paste and peptone water. A filtrate was inoculated on two special suspensions: a Sabouraud agar with glucose and a Sabouraud agar with Metocel and starch. Two filtrates from these suspensions were separated chromatographically on Sephadex G-100. The biological activity of the enzymes found in the filtrates was determined as follows:

proteases 11.3 U = 11.3 µg/min.
α-amylase 5.1 U = 5.1 micro-equivalent/min.
cellulase 1.1×10^{-2} U/ml.

By moistening the paste the cellulase is activated biologically so that it damages the original canvas of the painting. Therefore, glucose was used as a specific inhibitor of cellulase.

For removal of the paste two systems were used:

System I, consisting of wax, benzin, toluene and turpentine were used to prevent infiltration of system II into the painting, and
System II, consisting of 170 U/mg of lyophilised α-amylase of bacterial origin + 20 mAnson units/mg of lyophilised proteinase K of fungal origin + glucose 300mg/100ml.

The enzymes and the added glucose were adsorbed on carboxymethylcellulose in a phosphate buffer at pH 7.0. This resulted in a thick mass used to remove the paste from the back of the painting. After the removal of the paste the remainder of the glucose was removed by means of a thick suspension consisting of glucose oxidase and catalase, both adsorbed on cellulose powder of the type CF 11 in a phosphate buffer at pH 7.5 - 8.0.

The paint layer was consolidated by means of

System I. The back of the picture was moistened with turpentine and benzine. A filtration paper impregnated with the same mixture of solvents was attached to the back of the picture. The solvents and a pressure of their vapours prevented thus penetration from the paint layer of products resulting from an enzymatic breakdown of the paste.
System II, consisting of 170 U/mg of lyophilised α-amylase of bacterial origin was adsorbed on polyethylene glycol 1000. This thick mass with the amylase was used for removing the paste from the surface of the picture.

The final inhibition was performed by means of menadion in a solution of propanol by spraying into the back of the picture.

Introduction

The conservation of paintings has been hitherto concerned with the removal of earlier conservation materials. For example pastes used for the lining of paintings. This lining technique uses several paste mixtures which penetrate into each paint layer of the painting through heat and pressure. Therefore, in the lining of paintings it is not only a question of strengthening the canvas by ironing on a new linen cloth, but also of a consolidation of the paint and ground layers which have flaked off. There is no panacea in the form of a paste that can be used indiscriminately for every painting. The choice of paste is determined by the technical character of each painting and by the extent of the damage on it. Not every paste material (starch, glue, dextrine, casein, wax, resins and so on) can be used independently, but must be combined and emulgated with other substances which change their properties. However, these foreign substances cause a tension in the painting, makes it inelastic, induces changes in its hygroscopic properties and further microbial activity.

The removal of pastes of different compositions is not easy and due attention has not been paid to it. Pastes are removed from the back of the painting by scraping. This gives a smooth surface on the back of the painting so there is no relief that penetrates into the paint layer during the following ironing. However, a considerable quantity of the old paste is left behind in the painting and a new paste of a different character is ironed on the painting.

This conservation method gives the painting in the course of time a worse condition. This appears often in a very short time (about 10 years), if a painting is put in unfavourable conditions. This environment creates, however, favourable conditions for the development of micro-organisms. A painting placed in a more favourable environment will also be damaged in time, but the process is much longer.

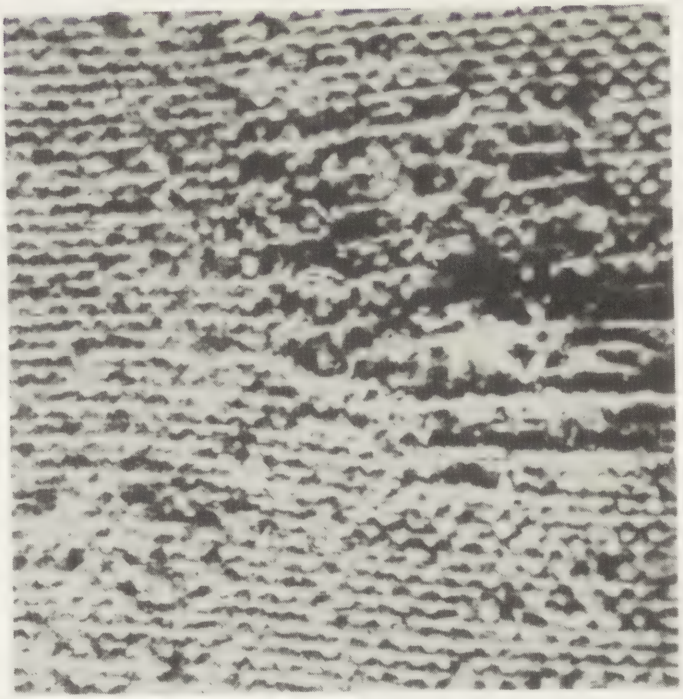
In our research we have paid special attention to the removal of pastes by means of enzymatic reactions. Such reactions can penetrate deeply into the painting. A typical characteristic of these reactions is that they cause relatively easily a lower activity of the enzyme present in the pastes. This depends on the complicated structure and the specificity of their effect. The inactivation of the pastes can be induced for instance by denaturation, viz. by altering their chemical structures by acting upon such external factors as the temperature or by changing the environment in which they are working.

A successful removal of pastes depends on the knowledge of painting technic and the detailed investigation of every component of the picture.

Examination of the painting

The picture was painted in the 17th century by an unknown Master with oil on canvas. According to prior information the picture has been lined. In 1969 the picture was lined again. The photo shows the white spots where the paste is present on the surface of the painting. The paste consisted of glue, Venetian balsam and meal.

Due to the presence of humidity mould developed. The mould from the paste grew into the cracks of the paint layer on the back of the picture.



A new canvas was put on the back of the painting. The photo shows several spots where the canvas has flaked off, owing to the action of the enzymes produced by the mould which have cleft the cellulose.

Solubility of pastes in distilled water

250 mg of a paste were put mechanically on different parts of a painting and the solubility of the paste in distilled water was examined in several samples. The results showed that the solubility varied according to the extent of mould damage on the paste. The highest degree of mould damage was found in the lower part of the painting, where 14% of the paste was dissolved after 1 hour at 20^{o}C. In the upper part of the painting 6.0% of the paste was dissolved at constant conditions. In the middle part of the painting 5.2% of the paste was dissolved at constant conditions.

The solubility of the paste was determined by means of a protein from the paste in the Brdicka solution. The quantity of protein was assessed by means of the calibration curve.(1)

Test conditions

The polarographic experiments were performed with the model E 261 R Polarecord made by Metrohm Ltd. Switzerland; the galvanometer sensitivity was $4{,}1.10^{-9}$A/mm. Starting voltage: -0.8V. Voltage range: -2.0V. In experiments with freely dropping capillaries the droptime was adjusted by choosing a suitable mercury pressure to 2 sec at the voltage of -1.525V, at which the second protein wave appears.
The Co^{2+} ammoniacal buffer solution had the following composition: 0.1M NH_4Cl, 1M NH_3, 0.001M $CoCl_2$.

Mould cultivation

The mould present in the paste was found to consist of Penicillium sp, Aspergillus fumigatus, some bacteria and yeasts. The extracellular enzymes produced by them were studied as well as their power of hydrolyzing pastes, the

canvas and the paint layer. The mould was inoculated on a Sabouraud agar with glucose and peptone water at a buffer pH 7.0 where they grew.
The filtrate was inoculated on two special suspensions:
a) A Sabouraud agar with lining paste and
b) A Sabouraud agar with Metocel and starch

After 5 days, when the growth of the micro-organisms was maximum, the microbial mass was removed from the filtration substrate and the filtrate was used for isolation of the enzymes.

Method of determining the activity of the proteases present in the filtrate

1. As an operation of essential importance the proteases were separated chromatographically on Sephadex G-100. The extract was prepared by extracting the pulverized dry substance of the filtrate during 30 min. in a 0.05M buffer with 5 ml sodium acetate and 5 ml calcium acetate for each gram of dry substance. 3 ml of this solution were put on the column and eluted at a constant buffer. The enzymes were purified by means of ion exchange chromotography on DEAE cellulose of the type DE-52.

2. Since proteases catalyze the degradation of nitrated casein in the same way as the degradation of natural casein, 1 ml of the proteases isolated according to point 1 above was mixed with 20 mg of nitrated casein in a solution of 1 ml of 0.07M phosphate buffer at pH 7.4. The reaction occurred at 37°C during 60 min.

3. 2 ml of 0.1M trichloroacetic acid (0.2M acetic acid + 0.2M sodium acetate) was mixed with the product of the reaction according to point 2 above. This mixture was centrifugalized. To the supernatant a 0.3M solution of sodium carbonate was added and the intensity of the yellow colour was measured spectrophotometrically.

4. The ΔA_{436} in the supernatant was measured spectrophotometrically.

Result:
The proteolytic activity of the proteases was expressed in protease units (U), 1 U being defined as the amount of nitrated casein in µg which reacts with the proteases under the above described test conditions during 1 min.
In the present case it was found that the activity was 11.3 U = 11.3 µg of nitrated casein/min.(2,3,4)

Method of determining the activity of the α-amylase present in the filtrate

1. As an operation of essential importance the α-amylase were separated chromatographically on Sephadex G-100. The extract was prepared by extracting the pulverized dry substance of the filtrate during 30 min. in a 0.05M buffer with 5 ml sodium acetate and 5 ml calcium acetate for each gram of dry substance. 3 ml of this solution were put on the column and eluted at a constant buffer.

2. 1.0ml Zulkowsky starch in a solution of 0.016M sodium acetate buffer (10mg/ml)at pH 6.0 was mixed with 1 ml of the amylases isolated according to point 1 above. The reaction occurred at 25°C during 15 min.

3. 2.0ml 0.04M 3.5-dinitrosalicylic acid, dissolved in 0.4N NaOH(1.06M potassium sodium tartrate), keep at 100°C for 5 minutes then make up to 20.0ml.

4. The ΔA_{490} in the supernatant was measured spectrophotometrically by measuring the intensity of coloration of the alkalized supernatant.

Result:
The activity of the amylase was expressed in amylase units(U), 1 U being defined as the amount of amylases which under the above described test conditions releases 1 micro-equivalent of reducing groups during per minute(calculated as maltose).
In the present case it was found that the activity was 5.1 U = 5.1 micro-equivalent/min.(5)

Method of determining the activity of the cellulase present in the filtrate

1. As an operation of essential importance the cellulase were separated chromatographically on Sephadex G-100. The extract was prepared by extracting the pulverized dry substance of the filtrate during 30 min. in a 0.05M buffer with 5 ml sodium acetate and 5 ml calcium acetate for each gram of dry substance. 3 ml of this solution were put on the column and eluted at a constant buffer.

2. 3.10^{-5}M of resorufin acetate were mixed with 0.01M tris buffer at pH 7.0 and 1 ml of the cellulase isolated according to point 1 above. The reaction occurred at 25°C during 2 min.

3. The ΔA_{540} in the supernatant was then measured spectrophotometrically by measuring the intensity of coloration of the supernatant.

Result:
The activity of the cellulases was expressed in cellulase units(U), 1U being the amount of cellulase which causes resorufin acetate to change into resorufin during a minute. In the present case it was found that the activity was $1,1.10^{-2}$U/ml.(6)

The examination of the action of enzymes isolated from the paint layer and the canvas of the picture has given the following results:

The paint layer was not hydrolyzed by the above mentioned enzymes. Between the canvas and the ground layer there was no proteinic isolation that could be damaged at the given conditions.
The original canvas of the painting was damaged by the enzymes produced by the cellulase. The composition of the original paint layer did not act upon the above mentioned enzymes of the inhibition. New cements effected a partial inhibition, owing to the chalk and the red cadmium used for retouch. Further inhibition was induced by the anilin colour stuffs of the text added on the back of the painting which had penetrated into the paste. Cellulase caused damage on the canvas of the picture. The cellulase was examined separately from the other enzymes. During the enzymatic hydrolysis the presence of humidity was necessary, but the humidity induces biological activity in the cellulase. Therefore, it was necessary to inhibit the cellulase, in order to prevent a more serious damage on the canvas of the picture.

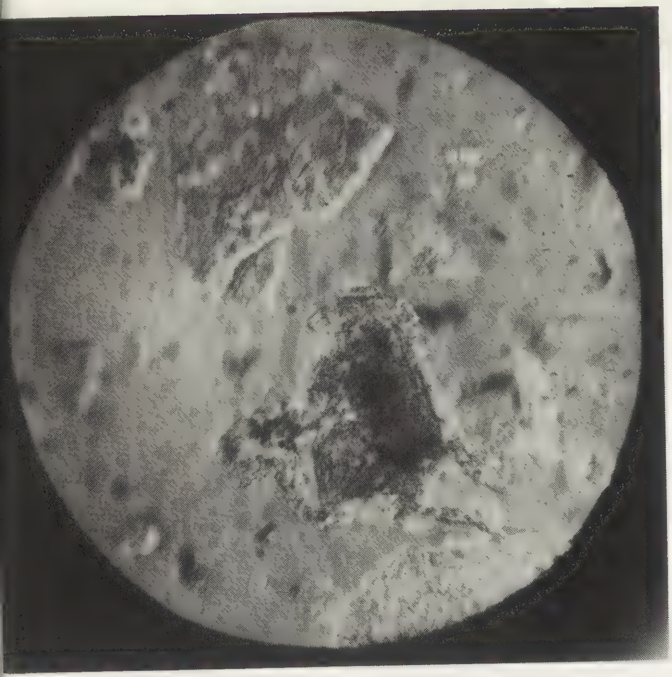


Photo of the cellulase isolated from the culture filtrate, 450 x.

In order to determine the cellulase activity the behaviour of the cellulase was examined at the same conditions as during the removal of the paste.

Removal of the paste

The results obtained concerning the cellulase makes it possible to draw some conclusions for the removal of the paste:

Change of pH values cannot be used for removal of the paste, because cellulase at pH 8.0 has a 10% activity. At this pH value or greater the paste cannot be removed, as this would cause damage on the canvas layer in such an alkaline range. An analogous situation arises in the acid range. At pH 4.0 cellulase has a 20% activity, and such a highly acid environment, pH 4.0 or lower, would induce damage on the linen painting.

Change of temperature can be used for removal of the paste. From the results obtained it appears that cellulase does not have any activity below 15°C or over 40°C. In this case it would be possible to use for the hydrolysis of the paste bacterial amylase which shows a 80% activity between 40°C and 50°C. Yet, the problem remains how to prevent, at such temperatures, the painting surface from being damaged by the intruding products of the enzymatic hydrolysis. The best method is to use glucose as specific inhibitor of the cellulase and to work at the environment temperature 20°C.

For removal of the paste the following systems were used:

System I: wax, turpentine, benzine and toluene.

System II: α-amylase, proteinase K and glucose. The enzymes were adsorbed on carboxymethylcellulose in a phosphate buffer at pH 7.0.

Japanese ricepaper was attached to the paint layer using wax, turpentine, benzine and toluene(system I). The painting strengthened in this way was then coated with melinex. Thus, the painting was prepared for the removal of the paste from the back of the painting. The proportions in each system are very important. If the system is permeated with a liquid or solid substance, an increasing liquid state arises at certain conditions on the liquid or solid substance resulting in an increasing volume of the whole system. Using this premise the second system, aimed at removing the paste, was prevented from penetrating into the paint layer. The pressure of system I can be controlled(7). If removal of the paste requires a longer time and the pressure of system I diminishes considerably, it is necessary to use system I once again. The paste was removed by means of 170 U/mg lyophilised α-amylase of bacterial origin(Enzyme unit 1 U is defined as that quantity of enzyme which under test conditions liberates 1 micro-equivalent of reducing groups per minute calculated as maltose), 20 mAnson units/mg lyophilised proteinase K of fungal origin(Enzyme unit 1 Anson unit is defined as that quantity of enzyme which under test conditions liberates 1 μmole of Folin-positive amino acids per minute calculated as tyrosine) and 300 mg/100ml glucose bound to carboxymethylcellulose dissolved in a buffer of sodium acetate at pH 7.0.

Glucose was used as specific inhibitor of the cellulase(8). In the above mentioned concentration the inhibitoring effect of glucose was immediate. After the paste had been removed from the linen painting a part of the paste remained in the deep layers of the canvas together with glucose. The removal of the remainder was easy to perform by means of glucose oxidase and catalase. Since the formation of gluconic acid lowers the pH values with a unit the pH value used at the beginning was adjusted to 7.5 in the course of the reaction.

The enzymatic activity was determined polarographically. Glucose oxidase catalyzes the oxidation of β-D-glucose on D-gluconic acid. In the presence of catalase hydrogen peroxide is cleft and at the same time molecular oxygen is released. The whole course of both reactions can be characterized by the consumption of 1 atom of oxygen for the oxidation of 1 molecule of glucose. The activity of glucose oxidase and catalase was determined by evaluation of the two polarographic curves. The first curve corresponds to the reduction of oxygen on hydrogen peroxide, and the second one to the reduction of hydrogen peroxide on water. The limit current of the first reduction wave was characterized by a potential between -0.4V and -0.5V, and the limit current of the second reduction wave by a potential between -1.35 and -1.45V on calumel electrode.

For removal of the glucose the following enzymes were used:

12 U/mg of lyophilised glucose oxidase, where 1U is defined as that quantity of enzyme which under test conditions catalyses the transformation of 1 μmole of substrate per minute.
(1 μmole of oxygen = 32 μg corresponding to 1 μmole of glucose = 180 μg.)

550 U/mg of lyophilised catalase, where 1U is defined as that quantity of enzyme which under test conditions catalyses the transformation of 1 μmole of substrate per minute.

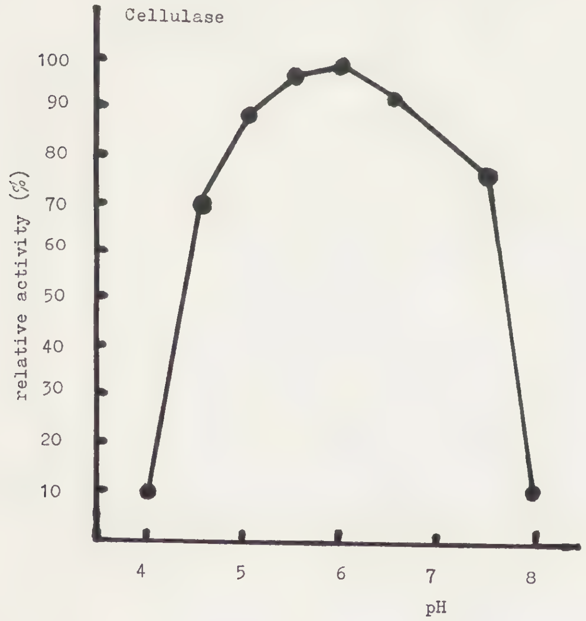
The removal of the glucose from the painting by means of the above mentioned enzymes was controlled on the back of the painting by measuring the changes of the pH values.
The glucose oxidase and catalase were adsorbed on cellulose powder of the type CF 11 in a phosphate buffer at pH 7.5 - 8.0. The time required for the removal of glucose was 1 hour.

The paint layer was consolidated by means of the following systems:

System I. The back of the picture was moistened with turpentine and benzine. A filtration paper impregnated with the same mixture of solvents was attached to the back of the picture. The solvents and a pressure of their vapours prevented thus penetration from the paint layer of products resulting from an enzymatic breakdown of the glue.

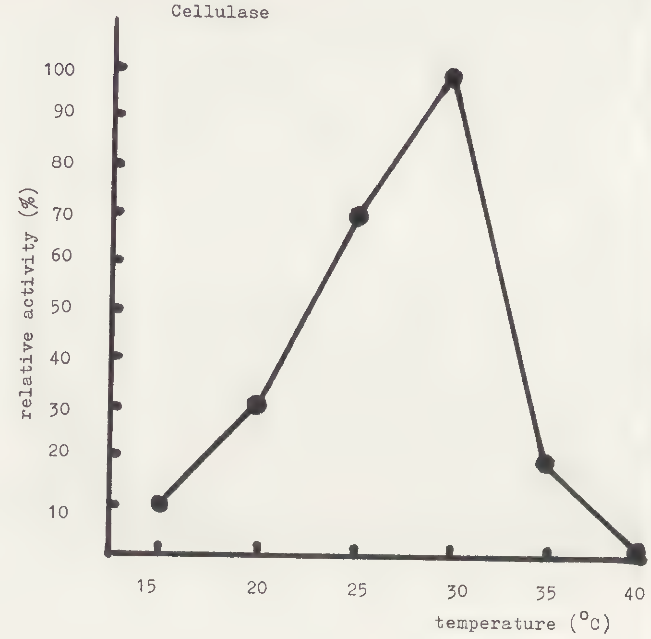
System II. Some quantity of α-amylase was adsorbed on polyethylene glycol 1000. This thick mass with the amylase was used for removing the paste from the surface of the picture. Polyethylen glycol 1000 was dissolved in a sodium acetate buffer at pH 7.0. 1mg of α-amylase was added to 1 g polyethylene glycol. The time required for removal of the paste was 15 min. Polyethylene glycol 1000, α-amylase and the products of the hydrolysis of the paste were then removed from the surface of the picture by means of turpentine.

Figure 1
Cellulase optimal activity



The cellulase produced by the above mentioned micro-organisms was found to have its optimal activity in the range of pH5.0 - 6.5. By extending the optimum range to pH 4.5 - 8.5 a 65% activity was still observed. By a further lowering of the optimum range to pH 4.0 - 8.5 the activity fell to 10%.

Figure 2
Cellulase activity from the canvas



The intensity of cellulase hydrolysis was measured at various temperatures. The activity maximum was reached at a temperature of 28°C. At 40°C no enzymatic activity could be measured. At 15°C the activity was minimal

From these results it appears that when the paste was moistened at temperatures below 15°C or over 40°C no hydrolysis of the original canvas by cellulase occured.

The whole inhibition was performed by menadion (vitamin K_3) and was considerably effective. Some pastes to which menadion had been added, were examined. It was proved that such pastes did not get mouldy. It is known that naphthoquinones are easily subjected to photochemical cleavage. Therefore, during the examinations light was screened off. The inhibition on the back of the picture was performed by spraying menadion in a solution of isopropanol in a ratio of 2 mg of menadion to 100 ml isopropanol.(9)

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COLD LINING AND ITS SCOPE: SOME CASE HISTORIES

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SUMMARY

Some case histories are presented as an illustration of the necessity to modify and improvise existing restoration techniques as according to the paintings at hand. The cold lining method emerges from the discussed restoration examples as a procedure that can be adapted to various anomalous conditions.

During the past fifteen years we have been working with dispersion as lining adhesive for canvas paintings, thereby using only little pressure and no heat. Relying on these adhesives we could successfully deal with various problems concerning the defects inherent in canvas paintings, such as weaken canvas in early paintings, deformation of paintlayer apearing as blisters, cupping etc., or paintings with heavy brush texture or even impasto, or thin paint layers and unvarnished mat surface. Moreover, the cases in which, because of restriction and preferences of museum authorities, the original varnish on a painting was on no account to be removed, but still, the paintin itself was in need of consolidation or of strip lining or even needed a full lining. Then there were also cases of large size paintings, where some improvisation of lining had to be carried out. This paper will review some of such cases in the sense of the scope and limits of the cold lining.

<u>Self portrait painting by Rembrandt from the Mauritshuis Museum in The Hague</u>

Three years ago the author was approached by the museum authorities with the request to examine the condition of this painting and to evaluate the conservation and lining possibilities. However this distinguished painting has never been lined before yet now it needed lining. And in view of the fact that next to the classical lining methods, a new one; the cold lining had come into existence, a discussion among the experts had to decide, which of the so far available method was the most appropriate for this particular painting.

After assessing the advantages and shortcomings of each of the available lining methods, the museum authorities decided upon the cold lining and they gave us the assignment to undertake the conservation of this masterpiece.

State of the painting:

As we mentioned earlier the painting has never been lined before. However, awhile examining it in our laboratory, we found that this painting had not only been lined with the starch paste method some time in the past, but the lining was afterwards removed and after that the painting was not relined again. The reason for the already discarded lining is not as yet clear. But for the sake of further study we made thorough documentation. The rest was clear: the condition of the canvas was very weak and brittle, the paint layer was in a fair good condition and had few cracks and only a light cupping of the paint surface and some wider cracks could be seen in the area of the headdress. The microscopic study revealed, that this area of paint was not very sound. According to the museum authorities, the painting has never been lent for any exhibition; at least not in the course of this century. Perhaps just because of this particular fact, the painting was, considering its age, in a good condition. In our opinion this painting could do without lining for yet a considerable period of time. However it needed some consolidation treatment. But according to plan, this painting was to lend for several exhibitions in various countries and the condition of its canvas was not strong enough to withstand the hazards of packing, unpacking and transportation. This being the case, the concerned authorities decided that a minimum of consolidation and lining should be carried out. Since this decision was based on reasons and criteria issuing from the uniqueness of this work of art, it was important that the condition and the physical behaviour of the paint layer and original canvas should be least influenced by the lining. Therefore our aim was to strive that the lining would serve only the purpose of supporting the original canvas and moreover that the adhesive would form only a film between the original canvas and the lining fabric. In this way the consolidation could be carried out only with the purpose of securing the paint layer, thereby avoiding any diffusion of lining adhesive into the composite material of the original painting. The cold lining method had the potential to attain this goal, as with it, the consolidation and the lining are distinctly two separate steps and materials employed are chosen accordingly. It was important in this context that the consolidation could be kept to minimum so that no excessive resin would remain on the painting, that afterwards could influence adversely both the paint layer and the varnish. Taking into consideration all these aspects, we have chosen to employ in this case the 'Dry Film and Reactivation Technique' form of the cold lining method. It has been discussed in detail in our paper (1234 and because of that only a short description of the steps is given below.

First step: After having removed the painting from the original stretcher, the edges were flattened. Then the painting was lined, starting from its edges on a provisional stretcher, on which non-woven nylon was stretched (see report no. 2, page no. 78/2/5/1-11)
The purpose of this sort of strip lining on a provisional stretcher was to facilitaet the whole process of conservation.

Second step: Improving the surface of paint layer and consolidation.

a. The painting was exposed to waterdamp and vapour of diacetone alcohol for about thirty minutes and then allowed to dry under pressure on the low pressure table. The surface condition of paint layer was thus improved.
b. Next 10% of Plexisol P550 dissolved in white spirit was used to consolidate the paint layer. This consolidant was sprayed on either side of the painting and allowed to penetrate the painting for about one hour before putting it on the pressure table. Although the percentage of consolidant was very low, it was in our observation sufficient in combination with the low pressure table to attain consolidation. The painting was left on the table to dry under pressure for about one hour. Although the painting was almost dry, still

it took quite some time before the whole amount of white spirit had evaporated.
Third step: Next day we proceeded as follows: (see also report no 1.2.3)

a. The adhesive Plextol B500 with Natrosol as thickner was applied on a stretched lining fabric through one of the screens (type HD 1200 (4). The fabric with adhesive film was left to dry at room temperature for about 45 minutes.
b. Ten minutes before the final lining the dried adhesive film was reactivated by spraying it with Toluene in the same manner one would varnish a painting: twice in sequence. The lining fabric thus procured with reactivated adhesive was then placed on to the pressure table. The provisional stretcher with the painting upon it was placed (see report no 2, page no 78/2/5/14). Then the painting was covered with Melinex foil and in that state was allowed to dry under a very low pressure, 10 cm w/c for about 30 minutes. The rest of the conservation work was finished off in the usual manner.

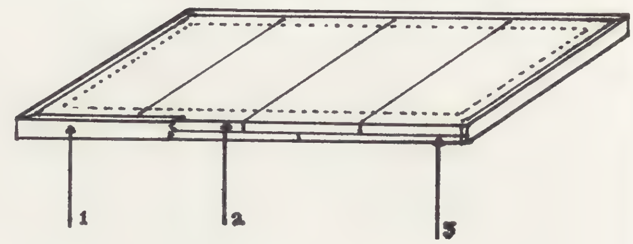
<u>Very large size paintings from early 20th century (2.3 m x 6.2 m & 2.3 x 9.8 m)</u>

These paintings in the townhall were regarded rather as a mural and even as a part of the interior architecture. It was therefore important to preserve their character and their function. For this particular reason it was decided to transfer them on a rigid support rather than on a fabric, which is an unusual practice in the conservation of canvas paintings. Yet this approach could help to maintain their wall-like characteristics. Considering the size of the paintings however a careful choice of materials for their support had to be made. The materials must be light in weight and stable, in order to withstand the dimensional changes of such vast painted areas. The other major requirement we had to fulfil was to design a restoration which was reversible. However, as a lining on a rigid support is not easily reversible, the original canvas in this case could not be attached directly to the chosen rigid support. That is, unless an interleaf was applied between the rigid support and the original canvas.
Bearing these aspects in mind we choose for the rigid support, the so-called Aerolam 'F Board' of CIBA GEIGY, which is, a light weight sandwich panel. These panels are of honeycomb aluminium network, covered with polyester and glass fibres on both sides, a coating of a very smooth textile like appearance. This material has, besides, a high structural impact strenght, is corrosion free and chemically resistant. The standard size is 244 cm by 122 cm. These panels are easy to cut in any form and to assemble no matter what sizes are involved.
As to the lining of these paintings it was clear that, with their very rough canvas a thin layer of ground and a quite thinly painted surface, they needed to be lined according to a method of which the lining adhesive would not penetrate into the original canvas. In order to make sure that we were acting right in considering for this project a modified cold lining system, we decided to carry out a dummy lining of 244 cm by 122 cm on Aerolam F Board. Thus we hoped to visualize all the necessary steps and modifications concerning materials and procedures alike. After the experience gained through the dummy we finalized our restoration plan. The entire lining process as we have carried out, is briefly outlined below:

1. Assembling the support: Several Aerolam F Boards of 25 mm thickness and size of 1.22 m by 2.44 m were put together so that they resembled the sizes and shapes of the three wall paintings. These panels were glued to each other with structural bond epoxy resin. Additional 10 cm wide strips of F Board were also glued at edges all along the panel, to give them structural strength (see drawing no 1).

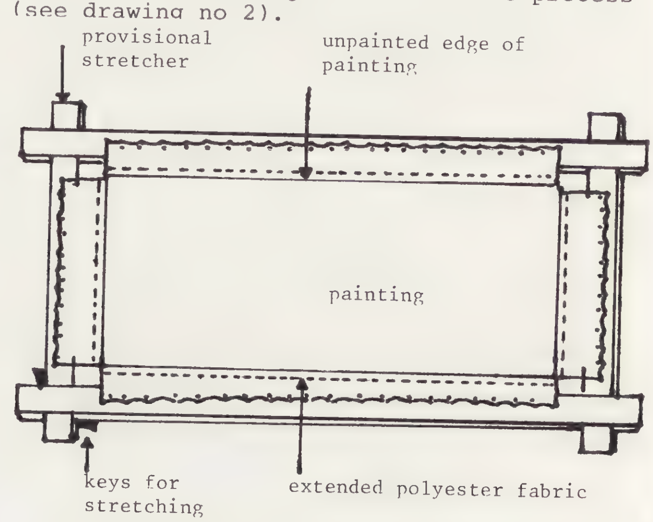
cross section

1. 'L'-shaped wooden profile
2. 'F' Board in standard sizes
3. 10 cm 'F' Board strip all along the edges



This made the total thickness of the panels 5 cm at the edges. The edges were then finished with a L-shaped wooden profile, also by means of epoxy bond adhesive. It was necessary to cover the edges with wooden profile so as to facilitate the attachment of the edges of the canvas painting to the panels.

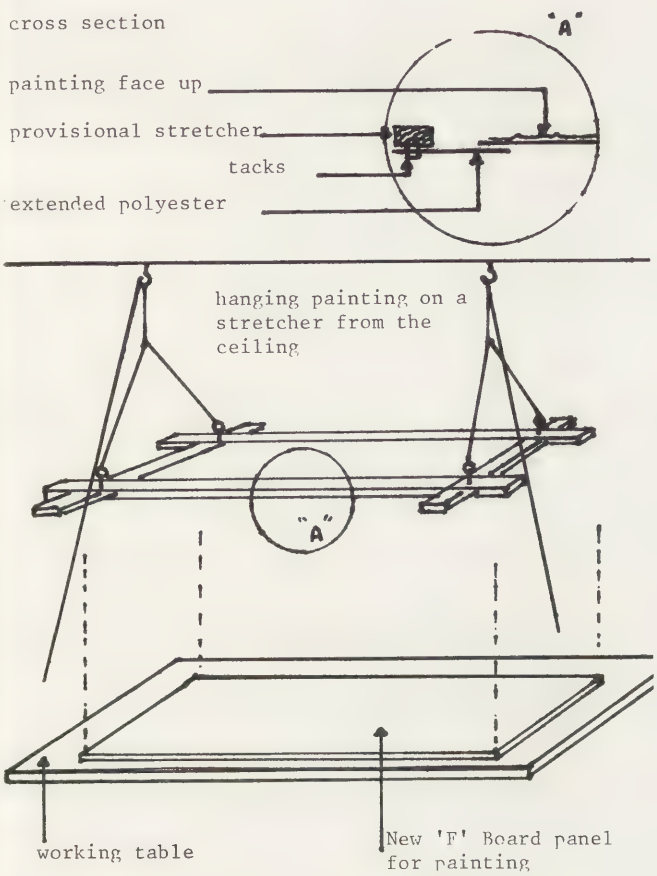
2. After having cleaned the residue of excessive glue as well as the remains of wall plaster which was still on the rear side of the painting, we extended the original edges of the painting by adding additional strips of polyester fabric all around it (as strip lining). This was found necessary considering the large size and its considerable weight. It was also important to mount it on a provisional stretcher which we had already constructed for this purpose. This was not only a safe design but it also facilitated all the steps throughout the entire process (see drawing no 2).



At this stage the painting was sprayed with a 2% solution of Magnesium Carbonate on the rear side, in order to deacidify it and was left for one day to dry.

3. Because of the enormous size of the

painting and the limited space for manoeuvering, the arrangement which followed the preceding stage, contained many and various improvisations. This is illustrated with drawing no 3.

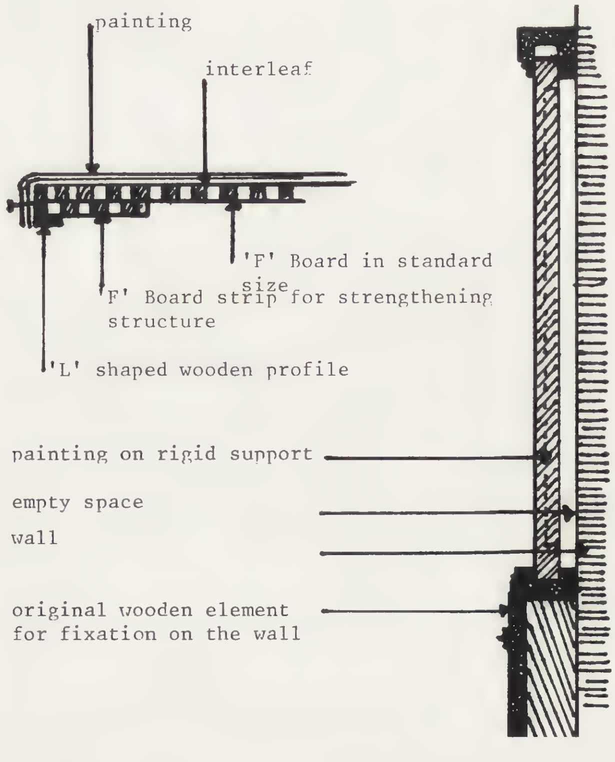


With this approach of hanging the painting with its provisional stretcher just above the working table, we managed to solve the problem of space and eliminated the risks in shifting the painting from one place to another whenever it was needed.

4. As the painting was pulled up above the working table, the assembled supporting panel was placed on the working table. Already in advance, it was exactly indicated where the painting would rest on the working table when lowered for the final lining. This position of the panel was maintained throughout the further steps. An interleaf of non-woven compressed nylon type no. 115 was dressed with Plextol B500 previously thickened with Natrosol. The interleaf absorved some of the adhesive during the application and also retained a very thin firm on its surface. This interleaf had also the function to minimise the peel off force, in case the lining would have to be reversed as an answer to any unforseen circumstances in the future. During the experimental lining of the dummy, it was observed that the interleaf had a weeker bond to the rigid support than to the canvas of the painting, which meant that in case of reversebility the painting would be peeled off along with the interleaf. This is certainly advantageous to the painting as the peel off forces involved by the separation would affect only the interleaf and not the painting's canvas.

5. As soon as we were ready with the preparation of the interleaf on the supporting panel, we could proceed with the final operation. We, however, discarded the technique of the adhesive film reactivated by sprayings with Toluene. Due to the size of the paintings we were afraid that we will not be able to reactivate such a large area of adhesive film homogenousely by spraying it with Toluene. Nor were we sure that in the presence of a reactivated Plextol film which behaves like a contact adhesive, we could manage to place the painting on the F Board panel without any degree of mismatching. What we actually needed was a glue with semi-contact-adhesive properties. So, instead of spraying a dried adhesive film, we decided to apply a layer of Plextol emulsion thickened with 15% Toluene, by means of a roller. Since the area that had to be covered with the emulsion was quite lrage, we were afraid that by the time we reached the last part of the panel, the area where we began to spread the Plextol would be almost dry. For this reason we added 5% of water to the adhesive emulsion to retard the drying process of the film. At the same time the 15% of Toluene-in-emulsion adhesive also reactivated the underlaying Plextol film which was before that brought on the interleaf. The advantage of this modification was that the Plextol adhesive was not as tacky as it would have been, were it only sprayed with the solvent Toluene.
After having applied the above mentioned mixture, we lowered down the painting with its provisional stretcher from the ceiling and could manipulate and readjust the painting at ease in case it took an awkward position. Then we covered the painting with wide polyethelene sheet and closed it like an envelop. To substitude the service of the cold lining table, we used a ventilator which we attached to the stretcher for the purpose of suction or pressuring or air circulation. According to our calculation, to get 10 cm water column pressure on the entire surface of the panel, we had to employ a ventilator of capacity of ± 1200 cubic meter of air transportation per hour. We proceeded by leaving the polyethelene envelop slightly open on one side so that the applied adhesive could dry. This process took about four hours.

The rest of the treatment included finishing of the edges, retouching, varnishing etc. All was carried out in the usual manner
The mounting of the painting on the wall as a loose interior element was quite simple, as shown in drawing no 4. The mounting is reversible.



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SOME ALTERNATIVES TO LINING

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SUMMARY

Uneven and badly cupped paintings are usually lined or stuck onto panels in an attempt to flatten the surface, but there are other less drastic treatments which can eliminate surface distortion.

Relaxation of the surface using moisture or solvent vapour is one. The removal of the moisture with the picture still under vacuum is often difficult. A practical solution is proposed. A simple method of strip lining is also described.

Paintings on canvas change with time. Their surfaces can become distorted and disfigured by wrinkling and cupping. Canvas sags unevenly and the corners become set with hardened creases. The image of the stretcher starts to be visible from the face and areas of crackle begin to appear, mostly in the upperpart of the picture, whilst the lower part often shows paint cleavage and losses. This description could apply the thousands of paintings all of which have deteriorated similarly over a period of time, often not more than eighty years, to a state of collapse. The usual remedy is to line a painting in this condition but we believe that less drastic measures can be adopted.

In the last few years relaxation treatments have been used by many conservators who introduce moisture or solvents into the paintings which are held onto suction or vacuum hot tables during the process.

We all recognize the danger of introducing moisture to the canvas of painting which has not been firmly attached to a support. Paintings of the 19th century are particularly prone to dimensional change and often contract rapidly on contact with water. It is possible to use other solvents to aid relaxation but water will always be one of the most useful and effective solvents to create the conditions where the paint layers and canvas are gradually persuaded to take up their former relative positions.

Badly deformed paint layers resulting from rheological movements of the paint in the process of aging can also be greatly improved and cupping caused principally by vehicular contraction can be reduced or even eliminated by heat/solvent vapour treatments.

One of the most common problems affecting all vapour treatments is the difficulty of removing the moisture in a way which still leaves the painting held in a level state. Some methods of extracting the moisture take many hours and even then, there is no certainty that the improved surface will remain when the vacuum pressure has been withdrawn. However most treatments of short or long duration must be terminated by the withdrawal of the solvent vapour without reducing the heat or vacuum pressure which holds the painting flat during the process. Using a vacuum hot table for this purpose can be a difficult operation as extraction is limited in volume

To overcome this difficulty we have arrived at a method of rapidly removing the solvent vapour without seriously reducing the amount of pressure necessary to hold the painting 'flat' on the table.

We use the following method:

1. Wide cracks and fissures in the paint layers should first be coated with a solution of Lascaux Acrylic Adhesive 498-20X in water with a small addition of a non-ionic wetting agent as Disponil 20 (this should be carried out at least 24 hours before relaxation treatment).
2. Switch on the hot table and introduce moderate heat (35° C).
3. Place the painting face down onto a film of thin Melinex or thin Polypropylene "SURLYN" (Hercules) sheeting which lies over a soft layer of 5 mm thick Polyurethane foam. A double layer of foam is best and provides a firm, yet adaptable couch for the surface of the painting.
4. Another sheet of Melinex is placed over the painting, and this should be cut larger than the painting but not put into position at this stage.
5. Breathers (for the evacuation of the air) should be placed between the Melinex layers and also under the foam which can thus be made firmer and more compact.
6. The canvas (the reverse of the painting) or, in some cases the film in contact with the canvas, is then <u>rapidly</u> sprayed with Lascaux Hydro-Sealer 750 and the cut Melinex sheet placed over it. Low vacuum pressure is then applied and increased after any wrinkles have been smoothed out of the Melinex. Heat is then increased (up to 50° C) and the vacuum pressure brought to 3½ ins of mercury. Lower pressures can often be used, but the application of pressure must be gradual and be related to the heat and resistance of the painting. The full vacuum pressure is only applied after some time has elapsed to allow for the gradual relaxation of the painting.

If one cannot put the painting face down for reasons of heavy impasto this relaxation method can still be applied to the painting in a face up position.

After the application of moisture and the painting is under slight vacuum pressure, paintings with high impasto may require some additional heat to rapidly soften the surface membrane. When a hot air blower is used the Polypropylene membrane becomes plastic and fully adapts itself to the paintings surface. When cool, it retains the surface topography as a permanent relief.

The drying time for moisture evaporation will consequently increase and could be 3 to 6 times longer in duration.

The layers would be in this case:
1. Hot table
2. Melinex
3. Polyurethane foam sheeting
4. Fibre glass (to help air flow)
5. Painting (face up)
6. Membrane, Melinex or 90 gauge Polypropylene "SURLYN" (Hercules).

Breathers (suction strips) placed in position as before, including one placed below the foam to increase its rigidity.

The acrylic emulsion used to spray the canvas is an acrylic/water dispersion of small particle size (0,06 micron). The pH is between 9 - 10 and is made by Lascaux in a 30% solution in water (Lascaux Hydro-Sealer 750).

The liquid sprayed onto the canvas is a dilution of 1 part of Hydro-Sealer to at least 4 parts of water. It is normally applied as a fine spray but can also be applied by brush. A very small amount is required as it penetrates deeply into the canvas. This liquid provides the necessary moisture for relaxation but also helps to consolidate weakened areas of the painting.

The method is simple in practice but experience is required to recognize the conditions when the vapour has reached its optimum effect and can be withdrawn.

Clearly, all paintings differ in their response to heat, solvents, and pressure, and the behavior of these factors will depend on the particular painting being treated.

However, some factors do seem to be constant and it is perhaps worth noting that the stage for moisture withdrawal is marked by a clear indication of moisture transfer from the canvas to the surface membrane.

If one touches the membrane at this stage, a clear image of a fingerprint is formed by moisture condensing on the inside of the film.

At this time the moisture should be withdrawn from the painting. This is achieved by making a small hole in the centre of the membrane film and then gently tearing a circular window of about 10 cms in diameter.

It will be soon be obvious that the open area is becoming paler and dryer, but does not show any sign of loss of tension. After a suitable pause (10 mins) the membrane is peeled back again making a larger window. This process is repeated until the whole of the back of the picture is uncovered. If the timing is correct no uneveness of canvas surface will be present.

Finally the vacuum and the heat can be reduced and eliminated. The painting should now be left to fully dry out and maintain its new equilibrium.

Should one observe any distortion of the surface within the window area at any stage, one should cover the back of the canvas with a fresh piece of film and reduce the vacuum pressure for a short period, and then repeat the previous treatment.

Distortion of the canvas is a sign that the withdrawal of solvent vapour is too rapid and more time should be allowed before widening the opening in the membrane.

The results of this method have been very successful and it is often not necessary to line the painting but merely provide some additional strength at the edges by strip lining before restretching. Strip lining is often very unfairly discredited as a method. Yet a number of very important paintings from the 17th century have survived with their paint surfaces unchanged because they were strip lined.

Certainly, in the past strip lining was seldom carried out without unwanted side effects.

The edges of the strip were often visible from the front. If glue paste was used this effect became very obvious. The use of other adhesives such as wax, or PVA, also brought difficulties and often poor adhesion. Rubber type adhesives became brown damaging the canvas.

More recently stable acrylic emulsions have been used and solvents have been added as thickeners. This reduces the dimentional change of the fabrics being coated.

Plextol emulsion combined with Toluol has been advocated by Vishwa Mehra as a lining adhesive. A Lascaux version with a high content of Xylol has been used for many years with success and is particularly suited for the purposes of strip lining. This is Lascaux Acrylic Adhesive 498-20X (Plextol with 20% Xylol). It is a pure Poly-Butyl-Methyl Methacrylate Emulsion with a particle size of 0,1 - 0,2 microns.

The method we use for strip lining is as follows:
First flatten the edges of the original painting. They should be dampened and gently flattened with an iron. Strips of a suitable fabric, slightly lighter in weight than the original, should be cut to size. The edges should be frayed. Undiluted Acrylic Adhesive 498-20X should then be spread evenly onto the edge of the original canvas. A similar coating is then applied to the reinforcing strip. the two coated surfaces are then pressed together by hand without stretching the strip in any way. This is important as distortion will result if any tension is used. Complete the remaining sides in a similar way. There is seldom a need for weights but should the edges be uneven this will be necessary. The amount of overlap depends on the condition and size of the original painting, but the width of the adhesive band can be as little as 1 cm for a small painting.

For a 'nap bond' type adhesion, a single coating on the strip is sufficient to bond the two surfaces, but one should remember that the peel strength will be reduced. In some cases this could be an advantage. The tensile strength remains high.

This adhesive can also be allowed to dry before the two surfaces are brought in contact with each other. Toluene can be used to activate the dry adhesive coatings which are then pressed firmly together and allowed to set. To accelerate the drying one can go over the strips with a warm iron so that the painting could be mounted on its stretcher within 3 hours if necessary.

This method of strip lining seems to us to be safe, rapid and effective, suiting old or modern paintings. We see it as a valuable way of strengthening paintings without altering their structural character and as means of postponing, perhaps for centuries, the need for lining.

When the moisture is seen to condense on the inside surface of the membrane, make a small hole in the film and with tweezers peel back the membrane in a spiral movement to make a circular opening.

Repeat at intervals gradually adapting the shape of the opening to suit the format of the painting. Continue until the canvas is totally uncovered.

The authors would like to thank Mr. Alois K. Diethelm of Lascaux Products for the valuable technical advice and practical help given in connection with this project.

Lascaux Acrylic Adhesive 498-20X and Lascaux Hydro-Sealer 750 are manufactured by Lascaux Farbenfabrik, Dept. Restauro, CH-8306 Brüttisellen/Switzerland.

Polypropylene "SURLYN" 90 gauge film is a product of Hercules Polymers Inc., Wilmington, Delaware 19899/USA and can also be supplied by Lascaux Farbenfabrik, CH-8306 Brüttisellen/ Switzerland.

LINING WITHOUT HEAT OR MOISTURE

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SUMMARY

This paper investigates some possible ways of achieving a reliable lining bond without the use of heat or moisture. Examined techniques are; solvent activation of dispersions, the use of Paraloid B72, acrylic pressure sensitive dispersions and the product Fabri-Sil.

A peel strength of 300g/2.5cm was defined as the minimum working requirement, it did not prove possible to achieve this in any method without the use of some organic solvent.

Plextol B500 was found to work satisfactorily when 'solvent activated', the relationship between applied solvent and bond strength has been determined. Primal AC634 proved unsuitable for this type of use.

Encouraging results were obtained using the very stable Paraloid B72 resin, though the method needs refining.

A total of nine acrylic pressure-sensitive dispersions were tested. The results were disappointing; only one producing an adequate initial bond strength. Even this proved unstable with time.

Fabri-Sil has been tested both with and without applied solvent. The relationship between solvent volume and bond strength was determined. In practice it seems that very good bonds can be achieved with relatively small volumes of applied petroleum spirit.

1. INTRODUCTION

Despite the developments in lining technology in recent decades it is still the case that most techniques involve a degree of operational risk to the painting. The dangers stem from the use of heat, pressure and moisture which occur in various combinations within particular methods. Of course not all paintings are vulnerable to these hazards and it is now common practice to utilise relatively low vacuum pressures (eg 1"Hg). Yet dangers still exist. This is primarily because the methods which we employ to detect sensitivity to heat and moisture are crude and haphazard, and it is compounded by the tendency of paintings to respond differentially across their surface. In addition there are many works, particularly those of recent origin, which it is self evident would respond adversely to any of heat, moisture or pressure. Such concerns have led workers to develop lining systems using no heat or relatively low heat, employed with water-borne polymer dispersions. Mehra(1) amongst others has shown that where the presence of moisture might be detrimental, cold linings could be performed utilising solvent swelling of pre-dried dispersion films. This effectively reduces the operational risks to only those arising from very low pressure and the presence of an organic solvent such as toluene. There are of course some paintings, for instance modern acrylic works, which would be affected by toluene. Fieux developed the trend towards minimising operational risk in lining still further by introducing Fabri-Sil (2), a Teflon-impregnated glass fabric with a silicone pressure-sensitive adhesive. It is said to be capable of producing satisfactory bonds merely by smoothing pressure of the hand. Thus heat, moisture, solvents and significant pressures are eliminated from the lining operation.

These attempts to minimise the operational risks in lining are clearly worthy of more detailed study. Whilst solvent activation has been reported in general terms there is no quantification of the technique particularly as regards the relation between bond strength and solvent volume.

Further the product Fabri-Sil has no reported independent investigation and the bonding performance is given under specific test conditions not employed at this Institute. In order for us to make a direct comparison of Fabri-Sil with other adhesive systems, it is necessary to test the material under our standardised conditions.

Beyond this the question might usefully be asked as to whether there are other suitable techniques for minimal lining. In particular acrylic pressure-sensitive adhesives, Paraloid B72 and self-applied silicones might all yield satisfactory results.

It ought to be emphasised that these types of methods are being investigated in order to expand the range of options open to conservators. Though this study investigates methods which avoid heat and moisture, we are convinced of the value of, and frequently employ both in treating deformations of canvas paintings. There are, however, occasions when it would be unadvisable to do so or when the lining operation itself needs to involve minimal risks.

Some general remarks concerning the work in this paper are necessary. It is obviously important in assessing different lining systems to define what constitutes a 'reliable lining'. This means having some standard for the desired bond strength. In this paper, peel strength and shear strength data have been determined as a measure of bond strength. Peel strength has been utilised as the most sensitive indicator of practical reliability. This is for three reasons:

a) it gives information as to bond uniformity

b) it gives information as to bond type, eg, nap, high wetting

c) it monitors resistance to out-of-balance shear forces. Paintings tend to experience different stress values within their different layers. The magnitudes of these internal and external stresses vary with RH and with the nature of the stretching system. They give rise to out-of-balance shearing forces (3) which tend to cause the painting or individual layers to deform out of plane, eg, cupping, flaking. To some extent peel strength can be regarded as monitoring resistance to these resultant delaminating forces. One example of them in lined paintings is the tendency of cupped regions to pull the lining fabric towards the front. If the peel bond is weak delamination would be expected. Often, though not invariably, low peel strengths occur together with low shear strengths.

A wide range of lining adhesives has now been tested at this Institute and given our test conditions we would regard a peel strength of at least 300g/2.5cm as a minimum working requirement. A strong wax/resin formulation (60% Beeswax, 40% Dammar) might produce 800g/2.5cm and intermediate wax formulations will produce around 500g/2.5cm,(4). Such observations might be said to lead to an empirical standard since wax/resin mixtures tend to be regarded by conservators as the weakest practical adhesives. At any rate

it is necessary to adopt a standard which recognises the dynamic nature of a painting structure, outlined above. It is not sufficient to derive standards from a simple consideration of the forces due to gravity on the mass of the painting.

No doubt bonding requirements will continue to be a subject for discussion, but it is our view that a significant proportion of paintings lined with peel strengths of less than 300g/2.5cm will delaminate in use, primarily because of the tendency of paintings to develop out of plane deformations. Failure at higher bond strengths is also possible and it is suggested that strengths in the region of 800-1000g/2.5cm ought to provide reliable linings which are not at the same time excessively overstrong. These values refer only to the specific test conditions and fabric samples employed at the Courtauld Institute. For marouflage systems which have no external stresses peel strength standards can be lower.

It is assumed in this study that paintings to be lined can be brought substantially into plane prior to lining. The lining is thus required to restrain only minor deformations.

2. EXPERIMENTAL

The experimental procedure utilised small scale simulated linings, with adhesives applied, in areas of between 100 and 130cm^2, to the lining fabric. This was necessary to allow a large number of variables and materials to be examined. Polyester fabric ("Permawear" Quality 970) was used as the support in the majority of tests linings and tests were also performed using polyester sailcloth as lining fabric. To simulate the paintings, three different types of primed linen canvas were employed (see Appendix), so providing an indication of the effect of canvas topography on bond strengths.

For comparison purposes hand linings were performed, using polyester fabric as the lining support, on samples of the three canvas types, with two commonly used wax/resin lining adhesives - bleached beeswax: Ketone Resin N (9:1) and bleached beeswax: dammar (6:4). The average peel strengths obtained are given in Table 1 below:

Bond strength increases in the order A, B, C due to increasing surface area available for bonding and enhanced interlocking effect. Type A canvas, being a fine open weave material, produced weaker bonds than B or C and was used for the majority of simulated linings since it provided a more exacting standard.

Where feasible linings were conducted without involving heat, moisture or organic solvents. In cases where lining involved activation of the adhesive by solvent, this was done by spraying, using a small electric spray gun, from a standard distance of approximately 40cm, and a system was devised for delivering a known amount of solvent for an area of adhesive. In certain cases, for higher solvent volumes, the solvent was applied in two batches, with a short delay or cover time between sprays, to avoid excessive saturation of the adhesive. The primed canvas samples were generally lined immediately after spraying with the activating solvent and were left to adhere on the cold table at standard settings, giving a pressure of 28cm water for the first 20 minutes, followed by 90 minutes at a pressure of 15cm water. For the dispersion adhesives, lining was performed a minimum of 24 hours after application of the adhesive to the lining fabric. Since all these tests were conducted upon simulations of lining using small areas of primed canvas and a variety of lining fabrics, in order to extrapolate data as to applied solvent volumes to a larger scale of lining, account must be taken of the relative reduction of edge effects on bigger areas of adhesive. Where relevant, attention is drawn to this in the text.

Specific exceptions to the general experimental procedure are noted in the text where appropriate.

2.1 Solvent Activation of Water-borne Acrylic Dispersions

The method of solvent activation of non-tacky acrylic dispersion adhesives, or dry-film cold-lining as it is called by Mehra, is a modification of the normal cold lining technique intended for use when a painting responds adversely to even small amounts of moisture. The adhesive, Plextol B500 is applied, in thickened form, to the lining fabric through a perforated screen and allowed to dry. The adhesive is activated or softened by spraying with toluene or propan-2-ol. The painting is then placed on the adhesive and left to adhere under low pressure on the cold table which aids in removal of the activating solvent.

This investigation sought to establish the variation in bond strength with the volume of activating solvent.

2.11 Plextol B500

Figure 1 (and also Tables 2 and 3) shows the variation of average peel strength for Plextol B500 with the total volume of activating solvent for both toluene and propan-2-ol. The adhesive, thickened with 1% Primal ASE-60 was applied to polyester fabric (Permawear, Quality 970) through a nylon net screen giving a dry coat weight of approximately 145g/m^2. Samples of Type A canvas were lined immediately after activation of the adhesive. A normal cold lining carried out using Plextol B500 applied under the same conditions produced an average peel strength of 1160g, with a maximum value of 1600g and a minimum of 730g.

Figure 1

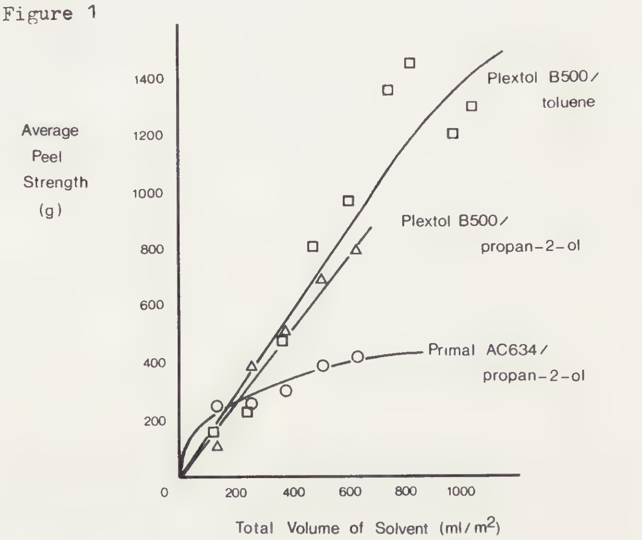


Table 1

	Average Peel Strength (g)	
Canvas Type	Beeswax:Ketone N (9:1)	Beeswax:Dammar (6:4)
A	300	500
B	370	770
C	475	950

Table 2: Plextol B500 activated with toluene

Cover Time (min)	1st Spray (ml/m^2)	2nd Spray (ml/m^2)	Total Volume (ml/m^2)	Peel Strength (g)		
				av.	max	min
-	single spray		118	150	350	40
-	single spray		236	220	315	130
3	181	181	362	470	755	190
3	236	236	472	800	1070	560
3	299	299	598	960	1180	750
3	370	370	740	1360	1770	1280
3	370	448	818	1450	1750	1100
3	450	526	976	1200	1450	850
3	445	594	1039	1300	1600	950

Table 3: Plextol B500 activated with propan-2-ol

Cover Time (min)	1st Spray (ml/m^2)	2nd Spray (ml/m^2)	Total Volume (ml/m^2)	Peel Strengh (g)		
				av.	max	min
-	single spray		126	100	245	55
-	single spray		252	380	690	170
3	189	189	378	500	1040	290
3	252	252	504	680	1090	320
3	315	315	630	700	1090	400

Plextol B500 produces bonds of 500g with solvent sprays of about $400ml/m^2$ for both toluene and propan-2-ol. Further increases in solvent concentration result in higher peel strengths. These are, however, relatively large volumes per unit area and are just within the limits of practical feasibility. It is likely that applying a given volume of solvent on a larger scale involves a greater concentration than was employed in the small scale tests, since edge effects are diminished. An application of $400ml/m^2$ of toluene or propan-2-ol should, therefore, achieve a practicable result around 800g.

Test linings were also performed using Plextol B500 thickened with 15% toluene rather than Primal ASE-60. For the same volume of activating solvent, the toluene-thickened adhesive gave significantly lower peel strengths. This was apparently due to greater seepage of the adhesive through to the reverse of lining fabric immediately after application, resulting in a reduced amount of adhesive at the interface of lining fabric and canvas samples.

The peel strengths for the three different canvas types, lined onto polyester fabric using Plextol B500, applied to the lining fabric as above and activated with $283ml/m^2$ toluene, are given in Table 4 below:

Canvas Type	Peel Strength (g)		
	av	max	min
A	350	575	185
B	500	715	330
C	600	925	365

Table 4

These results show the same trend of increasing peel strength in the order A, B, C that was observed for the wax/resin adhesives. Similar peel values were obtained with the three canvas types lined with Plextol B500, at the same level of activation, using polyester sailcloth as the lining fabric.

Shear strength tests were carried out on samples of Type A canvas lined onto polyester fabric with Plextol B500, thickened with 1% Primal ASE-60 (dry coat weight $145g/m^2$) solvent activated with single sprays of both toluene and propan-2-ol.

	Shear strength (Kg) Cross-head Speed 50mm/min
Plextol B500 activated with 299 ml/m^2 toluene	34.0
Plextol B500 activated with $456ml/m^2$ propan-2-ol	21.25

2.12 Primal AC634

Primal AC634 is commonly used as a cold lining adhesive; it generally produces slightly stronger bonds than Plextol B500.

Initial tests with Primal AC634, at coat weights of $135g/m^2$ and $270g/m^2$ using xylene as activating solvent, produced extremely low peel strengths - 50g and less, for solvent volumes as high as $750ml/m^2$. Propan-2-ol was found to be a more effective activating solvent: the variation of peel strength with total volume of propan-2-ol applied, for Type A canvas lined with Primal AC634, thickened with 2. Primal ASE-60 (coat weight $135g/m^2$) onto polyester fabric is shown in Figure 1.

A conventional cold lining performed with Primal AC634 under the same conditions gave an average peel strength of 1240g.

These results show that Primal AC634 is unsuited to the technique of lining by solvent activation. Reliable bonds are difficult to achieve; this arises from the relative lack of response of the adhesive to solvents.(5).

2.2 Solvent Activation of Acrylic Resins

During experimentation with solvent activation of acrylic polymer dispersions, the possibility of using an acrylic resin, specifically Paraloid B72, as the lining adhesive was suggested. As resins are utilised in solution they are obviously readily swollen by solvents and experience with B72, both as a varnish and as a retouching medium, indicated that considerable tack was developed with low solvent con-

tent. Paraloid B72 is regularly used as an adhesive in archaeological conservation.

Paraloid B72 is generally regarded as one of the most permanent organic materials used in conservation. The principal motivation for its inclusion in this investigation was the possibility of using such a stable material as a lining adhesive.

Test linings with Paraloid B72 were carried out using polyester sailcloth as the lining support; it was felt that, being less porous than the Permawear polyester fabric, the sailcloth would take a continuous film of adhesive, built up in a number of sprayed coats, more readily.

In lining by solvent activation of B72 bond strength is not directly proportional to the volume of activating solvent. Bonding is dependent on generated tack. Excessive solvent sprays result in the adhesive becoming fluid and, consequently in migration away from the interface during lining. The desired condition for bonding is best described in terms of visual and tactile observations. When activated by solvent, the adhesive film becomes very glossy and a high degree of tack is developed - a finger pressed lightly onto the surface and pulled away after a short contact time feels noticeable resistance and pulls fine strands of adhesive with it.

It was found that uniform activation could most easily be achieved by spraying, not with toluene, but with a further solution of B72 in toluene (20%). If, after initial spraying, gloss and tack do not appear to be uniform, further local sprays of B72 solution can be applied to deficient areas or the entire adhesive film can be left for a short while for the solvent to evaporate and then be reactivated completely.

Table 5 shows the average peel strengths achieved by this method for Type A canvas, at different coat weights of adhesive, and the variation of peel strength with time after lining.

	Average Peel Strength (g)		
Coat Weight (g/m^2)	48 hours	72 hours	8 weeks
104	1550	2350	2250
135	1800	1750	2000
160	1500	2750	3200

Table 5

The method is capable of producing very strong bonds with low solvent spray volumes. The steady increase in bond strength with time after lining is probably due to the slow evaporation of solvent. A number of experimental linings have been performed on student paintings using this method, with satisfactory results.

2.3 Pressure-Sensitive Adhesives

Pressure-sensitive adhesives are visco-elastic materials that in a dry, solvent-free state, are permanently tacky at room temperatures. Such materials will adhere to most solid surfaces on contact or under minimal pressure, without the need for activation by heat or solvent. Unlike other classes of adhesive, adhesion is not accompanied by a progressive increase in viscosity of the adhesive.

Pressure-sensitive adhesives can be divided into 2 major classes: (i) adhesives that are compounded to pressure-sensitive products by blending an elastomer with tackifying resins, plasticisers and other ingredients; (ii) adhesives which comprise polymers that are inherently pressure-sensitive and require little or no compounding. The acrylics and silicones fall into this category and it is likely that, of all the different types of pressure-sensitive adhesive available, only these will approach the stability required for conservation.

2.31 Acrylic Pressure-Sensitive Adhesives

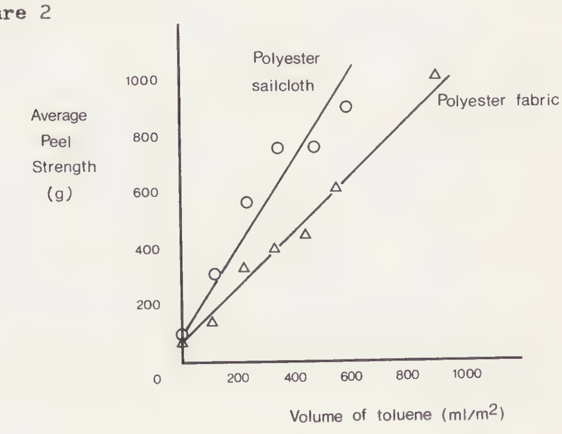
Acrylic pressure-sensitive adhesives are usually copolymers based on alkyl acrylates and methacrylates with 4 or more carbon atoms in the alcohol component. The most common monomers included to produce the desired tack are n-butylacrylate (Tg-54°C) and 2-ethylhexylacrylate (Tg-85°C). The adhesive properties can be varied considerably by copolymerization with acrylate and methacrylate monomers of higher Tg and a variety of other functional monomers, such as acrylic acid, acrylonitrile and vinyl acetate may be introduced depending on the properties required.

A number of acrylic dispersion pressure-sensitive adhesives, giving a complete range of tack, adhesion and cohesive strength properties were obtained from manufacturers for evaluation. The adhesives tested were as follows: Primal N560, Primal N580 and Primal N1031 (Röhm + Haas), SPP100/072 (National Adhesives + Resins Ltd), WS3965 (Williams Adhesives), L936 (Bostik Ltd), J1022 (Henkel Chemicals), Plustex C1354 (Plus Products) and 9963SE 1310 (Industrial Adhesives). Only one, however, - Bostik L936 - showed any suitability as a lining adhesive, combining high tack and resistance to peel with high cohesive strength. The other adhesives were either very soft and tacky and failed cohesively on peeling, or were not sufficiently tacky and wet the canvas samples only very slightly.

Preliminary tests showed that although Bostik L936 performed significantly better than all the other acrylic pressure-sensitive adhesives, sufficiently high peel strengths could not be achieved without activation by solvent. (See Figure 2). As with solvent activation of Plextol B500, the peel strength was found to be strongly dependent on the volume of solvent applied per unit area of adhesive.

The variation of peel strength with total volume of toluene applied is shown in Figure 2, for both polyester fabric and polyester sailcloth lining supports. Bostik L936, thickened with 1.5% Primal ASE-60 was screened onto the lining fabrics giving a dry coat weight of $96g/m^2$. The adhesive was activated with toluene, applied in a single spray, and Type A canvas samples were used to simulate the painting.

Figure 2



The peel tests for the data contained in Figure 2 were conducted 48 hours after lining. Selected samples retested 8 weeks after lining have shown dramatic reductions in peel strength - over 50% in some cases. The reasons for such marked decreases in bond strength are unclear. In any event, the fact that initial adhesive strength is not retained is perhaps sufficient to discount L936 from practical use as a lining adhesive.

One reservation about the use of pressure-sensitive adhesives, in general, for structural applications is that, since they are soft, visco-elastic materials, they may be prone to "creep" or deformation in response to sustained stresses. The response of visco-elastic materials to stress is a rate-dependent process. In an attempt to assess the likelihood of creep occurring, shear tests were performed at a very low shear rate

Table 6	Shear Strength (Kg)	
	Cross-head Speed 50mm/min	Cross-head Speed 0.5mm/min
Not Solvent Activated	4.24	2.17
315ml/m^{2}Toluene	10.73	2.33
519ml/m^2 Toluene	18.43	2.25

(0.5mm/min), in addition to the normal tests using a cross-head speed of 50mm/min. (See Table 6, L936, thickened with 1.5% Primal ASE-60, coat weight 96g/m^2, on polyester fabric).

Lower values of shear strength are normally observed at slower shear speeds. If flow is not occurring, however, an increase in shear strength with volume of activating solvent should be observed at both shear rates. It is significant that, with L936, an almost constant low shear strength is observed for all levels of solvent activation, at a shear rate of 0.5mm/min. This is, therefore, an indication that the adhesive might creep in use.

2.32 Silicone Pressure-Sensitive Adhesives

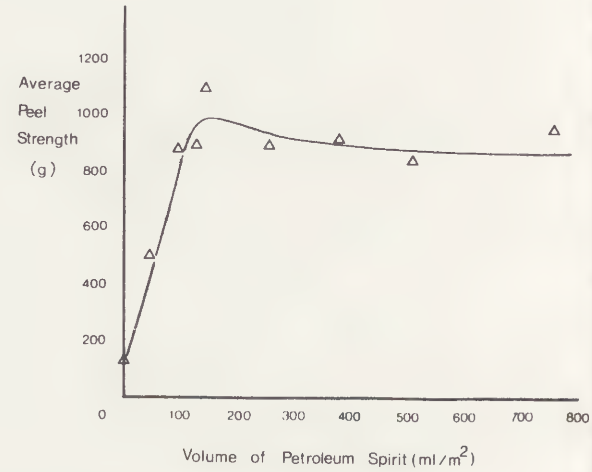
Silicones are semi-organic polymers (polyorganosiloxanes) of the general formula $(R_2SiO)_n$ where R can be alkyl or phenyl. They can be fluid, elastomeric or resinous depending on the type of organic groups attached to the silicon atoms, the molecular weight and the extent of cross-linking between polymer chains. Silicone pressure-sensitive adhesives are based on chemical combination of an elastomeric silicone gum and a silicone resin comprising a cross-linked siloxane network. The gum, which is a linear polymer of very high molecular weight, is condensed with the resin, and, in a similar manner to the formulation of acrylic pressure-sensitive adhesives, a variety of tack and peel adhesion characteristics can be achieved for silicones by varying the resin-to-gum ratio. The cohesive strength can be increased, without severely reducing tack or adhesion, by curing (cross-linking) with a catalyst, usually an organic peroxide.

Fabri-Sil

Fabri-Sil is a complete, ready-to-use lining material comprising both lining fabric and adhesive. It consists of Teflon-impregnated glass cloth coated with a cured silicone pressure-sensitive adhesive, and is supplied with a protective release layer for the adhesive. The composition of the adhesive is described in the specification of published European Patent Application No. 33193 which covers Fabri-Sil(6). Instructions given for using Fabri-Sil recommend simply placing the painting to be lined onto the adhesive and smoothing out with the hands to secure contact. The lining is then complete, although maximum bond strength is not reached for 72 hours. The adhesive bond achieved by this method is due entirely to the pressure-sensitive properties of the adhesive. The tack and adhesion of pressure-sensitive adhesives are increased by the presence of solvents; although the silicone adhesive on Fabri-Sil is not soluble in aliphatic hydrocarbon solvents it is readily swollen by them and, in the swollen state, exhibits greatly increased tack. The peel strength was again found to be dependent on the volume of solvent applied.

Table 7 shows the variation in peel strength with volume of activating solvent (petroleum spirit, b.p. 120-160°C) and the change in peel strength with time after lining. The petroleum spirit was, in all cases, applied in a single spray and Type A canvas was used to simulate the painting. Lining was carried out simply on a flat surface, not on the cold table, the canvas samples being lined immediately after activation of the adhesive. Figure 3 shows, in graph form, the dependence of peel strength on volume of activating solvent, for samples tested 48 hours after lining.

Figure 3



It can be seen that for Fabri-Sil bonds in excess of 500g are achieved by sprays of petroleum spirit greater than about 50ml/m^2. Peel strength increases in a roughly linear fashion with increasing solvent volume up to about 150ml/m^2. Further increases produce no significant change in peel strength.

As is the case for solvent activation of Plextol B500, increasing the scale of the lining operation will increase the effective volume of solvent per unit area, with the result that reliable bonds between 800g and 1000g should be produced by a solvent spray of between 50 and 150ml/m^2 petroleum spirit. In practice there are no advantages in activating the adhesive with solvent volumes higher than 150ml/m^2.

The reduction in peel strength in the early stages after lining that was observed with Bostik L936 was not evident with Fabri-Sil. Little difference was observed between the results of lining simply on a flat surface and those obtained using the cold table. A delay of 1 minute between activation of the adhesive and placement of the canvas samples was found to be significant for light solvent sprays only (less than about 125ml/m^2). It then produced a slight decrease in peel strength.

The peel strengths at various degrees of solvent activation obtained for the three canvas types in direct comparison, are given in Table 8.

The Teflon-impregnated glass cloth of Fabri-Sil is anisotropic, having 13 threads per cm in the warp (machine) direction and 8 threads per cm in the weft (cross) direction. Peeling in the direction of the weft threads produces a higher peel value than in the direction of the warp threads and produces a peel trace of different character. All figures quoted above are for samples peeled in the weft direction: in such cases, peel traces are characterised by a very constant average peel value, with sharp fluctuations between maximum and minimum peel strengths, indicative of a nap bond type system.

Shear strength results, for Type A canvas lined onto Fabri-Sil, are given in Table 9.

Table 7

Vol of Solvent	Peel Strength (g)								
	After 48 hrs			After 72 hrs			After 8 weeks		
(ml/m^2)	av	max	min	av	max	min	av	max	min
0	135	175	100						
47	500	710	330						
94	880	1190	600						
126	900	1240	660	930	1220	700	920	1080	750
142	1100	1380	850						
252	900	1220	660	1030	1400	720	970	1210	750
378	920	1370	620	900	1250	620	900	1360	540
504	840	1350	540	940	1340	580	880	1270	490
755	960	1260	720	1060	1400	820	920	1210	570

Canvas Type	Average Peel Strength (g)		
	Not Solvent Activated	$378ml/m^2$ Pet. Spirit	$441ml/m^2$ Pet. Spirit
A	130	1050	950
B	45	1100	800
C	175	900	880

Table 8.

Vol. of Petroleum Spirit	Shear Strength (Kg)	
	50mm/min	0.5mm/min
0	6.8	2.8
126	10.9	-
157	14.3	9.75
314	23.9	7.6

Table 9

It can be seen that, unlike Bostik L936, the shear strength at the slow speed for Fabri-Sil did not remain at a constant low value as volume of solvent was increased. This may indicate some capacity to resist cold flow of the adhesive. However, the reduction in shear strength between activation with $157ml/m^2$ and $314ml/m^2$ petroleum spirit suggests that high volumes of solvent cause some disruption of the adhesive film and should, therefore, be avoided.

A number of successful linings have now been performed with Fabri-Sil.

Although many adhesive manufacturers were contacted, only two suitable independent silicone pressure-sensitive adhesives could be identified: 280A and 282, both manufactured by Dow Corning. These adhesives are supplied as viscous solutions in xylene with solids contents of about 60% and require curing, after application, at 150°C with an organic peroxide catalyst. These are potentially very useful adhesives, but their physical form and high temperature curing render them impractical for small scale use by most conservators.

3. Conclusions

The ideal condition of a lining method that produces average peel strengths of at least 300g with minimal pressure, and without heat, moisture or solvents, was not achieved by any of the adhesive systems investigated.

Solvent activation of Plextol B500 is capable of producing a sufficiently strong bond for effective linings, but comparatively large quantities of toluene or propan-2-ol are required to create that bond. As already suggested, certain paintings will be excluded from treatment by this method. Primal AC634 is unsuited to the method of lining by solvent activation.

The use of Paraloid B72 as a lining adhesive shows considerable potential; this method produces very strong bonds with a low solvent content in the adhesive at the time of lining. Activation of the adhesive is, however, practically difficult and the procedure warrants further investigation if it is to give consistent results.

Although a wide range of acrylic dispersion pressure-sensitives were tested, this class of adhesive was rather disappointing. Only one showed any suitability as a lining adhesive, but this also required activation with considerable quantities of toluene to develop a workable bond strength. The marked decrease in peel strength that is observed in the early stages after lining probably precludes Bostik L936 from safe use as a lining adhesive.

It was noted that, without solvent activation, Fabri-Sil did not produce a bond that met our minimum requirements. With solvent activation, however, Fabri-Sil performs outstandingly, strong bonds being readily achieved with comparatively small quantities of a non-swelling aliphatic hydrocarbon solvent: a solvent spray of $50ml/m^2$ or more of petroleum spirit virtually ensures an average peel strength at a practical level between 500g and 1000g. Furthermore, an extremely uniform bond is generally produced. The time elapsed between activation of the adhesive and placement of the painting canvas is not, in practice, a critical factor affecting bond strength. This permits an unhurried lining operation and careful positioning of the painting with respect to the lining fabric. Although Fabri-Sil does not provide the conservator with a choice of lining support, the Teflon-impregnated glass cloth has favourable properties in that it is stable and exhibits high stiffness.

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5. Howells, R. et al, "Polymer Dispersions Artificially Aged", IIC Congress, Paris, September 1984

6. European Patent Application, Publication No. 0033193, 5.8.81 (Application No. 81300080.9), Applicant: General Electric Company, Inventor: D.F. Merrill

APPENDIX 1 - Details of Materials

1. Canvas Samples:

Type A - medium/fine weight acrylic-primed linen canvas, open plain weave
12 warp threads/cm^2, 12 weft threads/cm^2
weight - 380g/m^2, mean thickness - 0.446mm

Type B - fine oil-primed linen canvas (Winsor + Newton "Herga"), plain weave
16.5 warp threads/cm^2, 24 weft threads/cm^2
weight - 390g/m^2, mean thickness - 0.432mm

Type C - coarse jute canvas, oil-primed, plain weave
6 warp and 6 weft threads/cm
weight - 436g/m^2, mean thickness - 0.632mm

2. Lining Fabrics

Permawear polyester fabric, Quality 970: weight 204g/m^2
Supplier: Permawear Fabrics
Darwil House
Nelson
Lancashire, England

Polyester Sailcloth, Quality 00169/1A, Brand 18L, Weight 171g/m^2
Supplier: John Heathcoat + Co Ltd
Tiverton
Devon, EX16 5LL, England

Fabri-Sil
Supplier: John G. Shelley Co Inc
Art Sciences Division
16 Mica Lane, Wellesley Hills
Massachusetts 02181, USA

3. Adhesives

Plextol B500 - (Röhm GMBH) Supplied by Cornelius
Chemical Co
Ibex House
Minories, London EC3N 1HY

L936 - Bostik Ltd, Ulverscroft Road, Leicester LE4 6BW

Primal (Acrysol) ASE-60, Rohm + Haas (UK) Ltd,
Lennig House
2 Masons Avenue
Croydon
CR9 3NB

APPENDIX 2 - Test Conditions

Machine: Instron 1026

a) Peel Strength: Performed at 2mm/min on 2.5cm (1") wide strips, peeled for lengths of 5-8cm.

b) Shear Strength: Performed at 50mm/min with a bonded area of 6.45 sq. cm. (1 sq. inch).
Special slow shear tests at o.5mm/min were also carried out with pressure sensitive adhesives.

INFLUENCE DES POSITIONS RESPECTIVES DES TOILES DE DOUBLAGE ET TOILE SUPPORT DE PEINTURE (CHAINES CROISEES OU PARALLELES) SUR LES PROPRIETES DE RENTOILAGE A LA COLLE

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RESUME

L'influence de la disposition symétrique ou antisymétrique des toiles de doublage et des toiles support de peinture sur la stabilité dimensionnelle, la résistance au fluage, l'élasticité et la tenue au décollement de divers rentoilages ont été étudiées dans le cas de 8 rentoilages effectués par 2 artisans. Il s'avère que le sens de croisement des toiles présente une importance particulière pour la tenue au fluage, la résistance au décollement et l'élasticité des rentoilages. La stabilité dimensionnelle des rentoilages ne semble pas influencée significativement par le croisement ou non des toiles de doublage et de peinture.

I - INTRODUCTION

Parmi les causes à l'origine de la formation des craquelures de la couche picturale, les variations dimensionnelles des toiles support sont certainement une des plus importantes. Ces variations dimensionnelles peuvent être le résultat d'un mécanisme relativement lent et qui sera constaté surtout pour des tableaux lourds ou provenir de réactions extrêmement rapides dues au changement d'hygrométrie de l'air ambiant qui modifie les propriétés rhéologiques des colles et textiles cellulosiques (1).

Cette réaction des toiles aux changements d'ambiance est d'amplitude différente selon que l'on examine le sens chaîne ou trame des tissus (2 et 3). Au terme d'un certain nombre de travaux conduits sur le décatissage des toiles de lin et les rentoilages à la colle, il est apparu nécessaire de déterminer si le fait de disposer une toile de doublage chaîne parallèle ou chaîne croisée par rapport au support de peinture pouvait avoir une influence quelconque sur les propriétés du rentoilage. Les rentoileurs ne semblent d'ailleurs pas apporter une attention particulière sur ce point.

Pour effectuer cette étude et éventuellement dégager des règles de mise en oeuvre utiles aux rentoileurs, des rentoilages avec chaînes parallèles et d'autres avec chaînes croisées ont été confectionnés par des artisans du Service de restauration des Musées Classés et Contrôlés du Palais du Louvre.

Des tableaux fictifs ont été préparés pour ce travail, l'un sur une toile légère, l'autre sur une toile forte. Les rentoilages de ces tableaux fictifs ont été effectués sur une toile de lin décati. Deux rentoileurs ont fait cette opération permettant de disposer, donc, de 8 rentoilages expérimentaux. Sur ces échantillons, les études de laboratoire ont permis de déterminer :

- le comportement à l'état tendu sous l'effet de variations climatiques simulées en enceinte ;
- le comportement élastique et l'aptitude au fluage ;
- la résistance au décollement.

II - CARACTERISTIQUES DES MATERIAUX POUR LA CONFECTION DES RENTOILAGES

Tableau 1

Caractéristiques des matériaux de base.

Caractéristiques	Toiles support de peinture	
	Légère	Forte
Masse surfacique (g/m²)	154	320
Compte en chaîne (fils/cm)	11,4	9,6
Compte en trame (fils/cm)	13,8	10,4
Embuvage des fils chaîne %	10	5
Embuvage des fils trame %	2	5
Titre des fils chaîne (tex)	55	154
Titre des fils trame (tex)	58,7	154

Les pourcentages de colle déposée pour faire les rentoilages ont également été déterminés :

Les rentoileurs déposent systématiquement plus de colle pour les rentoilages des tableaux fictifs sur toiles légères.

Le rentoileur n° 2 dépose moins de colle que le rentoileur n° 1 quel que soit le tableau.

Tableau 2

Caractéristiques	Toile de doublage 1	
	Non décatie	Décatie
Masse surfacique (g/m²)	375	341
Compte en chaîne (fils/cm)	17,4	17,0
Compte en trame (fils/cm)	13,5	12,6
Embuvage des fils chaîne %	20,5	13,4
Embuvage des fils trame %	1,3	1,2
Titre des fils chaîne (tex)	107	107
Titre des fils trame (tex)	109	110

Tableau 2 bis

Caractéristiques	Toile de doublage 2	
	Non décatie	Décatie
Masse surfacique (g/m²)	370	356
Compte en chaîne (fils/cm)	17,2	17,0
Compte en trame (fils/cm)	12,9	12,4
Embuvage des fils chaîne %	23	14,6
Embuvage des fils trame %	2,2	2,2
Titre des fils chaîne (tex)	110	110
Titre des fils trame (tex)	110	108

Le croisement des chaînes ne semble pas entraîner d'effet sur les taux de colle déposée (ceux-ci varient de 50 à 65 % - taux de colle sèche).

III - COMPORTEMENT DES RENTOILAGES FICTIFS EN ENCEINTE CLIMATIQUE

Une éprouvette de rentoilage de 20 x 50 cm est disposée dans le sens de la plus grande longueur, sur un équipement spécial où on lui communique une tension de 20 daN représentant la tension moyenne que supporte une peinture sur un bâti. L'équipement est ensuite placé à l'intérieur d'une enceinte climatique où les conditions suivantes sont réalisées tour-à-tour : 20° C/65 % HR - 10° C/35 % HR - 40° C/ 90 % HR et nouveau cycle jusqu'à 20° C/65 % HR.

Les variations de tensions sur l'éprouvette sont enregistrées en continu. Les courbes de la figure 1 illustrent le type de résultats obtenus dans le cas du tableau fictif sur toile légère rentoilée par le rentoileur n° 1. Des résultats identiques ont été enregistrés avec toutes les autres configurations (toile forte, 2ème rentoileur), ils indiquent :

Que les rentoilages se tendent aux transitions humide/sec et se détendent aux transitions sec/humide.

Que le fait de croiser ou non les chaînes des toiles de doublage et supports de peinture n'a pas d'effet particulier en ce qui concerne le comportement à l'état tendu lors de variations climatiques simulées. Pourtant, il a été vérifié que les toiles de doublage décaties seules présentent comme cela a été montré en Ottawa (2), des réactions de montée en tension aux conditions humides. La méthodologie d'examen retenue pour les essais ne permet plus ici de mettre en évidence les réactions spécifiques de toiles de doublage, ceci peut être attribuable, soit au fort taux de colles mis en oeuvre dans le rentoilage, soit au fait que les conditions de tension appliquées initialement aux composites sollicitent essentiellement le film de colle.

IV - ELASTICITE - FLUAGE

IV.1. Mesure des paramètres élastiques :

Une éprouvette de 10 x 20 cm est découpée dans chaque rentoilage et soumise, dans le sens de la plus grande dimension, à un essai à vitesse lente (0,5 mm/mn). La tension, est relâchée, à la même vitesse, puis un deuxième cycle est repris, après un temps de relaxation de 15 mn.

Ce type d'essai permet de calculer un rendement élastique après chaque cycle. Les résultats obtenus sur toiles de doublage seules et sur les rentoilages sont regroupés dans les tableaux ci-dessous :

Toile de doublage seule

	sens de mesure	Rendement élastique 1er cycle %
Rentoileur n° 1		
Toile non décatie	S. Chaîne	23
	S. Trame	36
Toile décatie	S. Chaîne	43
	S. Trame	42
Rentoileur n° 2		
Toile décatie	S. Chaîne	30
	S. Trame	47

A l'analyse de ces résultats relatifs à la réponse élastique des rentoilages, il apparaît donc un certain avantage à disposer les chaînes des toiles parallèles, surtout dans le cas où la peinture est sur une toile support forte. Pour une peinture sur toile légère, cet avantage est moins net : le fort taux de colle utilisé dans ce cas est peut-être suffisant pour pallier aux réactions symétriques ou antisymétriques des deux toiles.

Tableau sur toile légère

	Sens des croisements: Tableau	Doublage	Rendement élastique 1er cycle
Rentoileur n° 1	Chaîne	Chaîne	61
	Trame	Trame	51
	Chaîne	Trame	64
	Trame	Chaîne	67
Rentoileur n° 2	Chaîne	Chaîne	73
	Trame	Trame	72
	Chaîne	Trame	72
	Trame	Chaîne	62

Tableau sur toile forte

	Tableau	Doublage	Rendement élastique 1er cycle
Rentoileur n° 1	Chaîne	Chaîne	69
	Trame	Trame	65
	Chaîne	Trame	65
	Trame	Chaîne	72
Rentoileur n° 2	Chaîne	Chaîne	75
	Trame	Trame	79
	Chaîne	Trame	66
	Trame	Chaîne	69

IV.2. Comportement au fluage :

L'essai est réalisé sur éprouvette de 25 x 50 cm prélevée dans les rentoilages. Dans la direction de la plus grande dimension de ces éprouvettes, on exerce une force constante égale à 50 % de la charge de rupture (cette charge de rupture est préalablement mesurée lors d'un essai de traction). L'essai de fluage est prolongé jusqu'à la rupture. Les courbes de la figure 2 donnent l'allure générale du fluage (allongement en fonction du temps) des divers rentoilages : sur ces courbes, les sens de croisement sont repérés dans l'ordre suivant : toile support de peinture - toile de doublage.

Ces courbes révèlent la très grande importance, au moment du rentoilage, de disposer le sens chaîne de la toile doublage dans la bonne direction. Malgré l'opération de décatissage qui rectifie considérablement l'embuvage des fils chaîne de la toile de doublage et donc diminue son aptitude au fluage, il sera plus intéressant de disposer le sens trame de la toile de doublage dans le sens d'application de l'effort maximum.

V - RESISTANCE AU DECOLLEMENT

Ces essais ont été entrepris pour apprécier la résistance du collage entre tableau fictif et toile de doublage, donc donner une une idée sur la réversibilité de l'opération. Les mesures ont été faites avant et après vieillissement dans l'enceinte climatique. Pour cet essai de décollement des éprouvettes de 50 mm de largeur et de 200 mm de longueur sont prélevées dans les rentoilages. Le décollement est amorcé dans le sens de la plus grande dimension et poursuivi sur machine

le traction à une vitesse de 100 mm/mn. La force moyenne de décollement est calculée en 5 points de l'enregistrement.

Les résultats apparaissent dans lestableaux ci-dessous :

Tableau 5

	Sens toile tableau	Sens toile de doublage	Rentoileur n° 1 Avant essai climatique	Après essai climatique
Toile légère	Chaîne	Chaîne	3,55	3,49
	Chaîne	Trame	3,44	3,53
	Trame	Trame	3,74	3,47
	Trame	Chaîne	3,48	3,66
	Moyenne		3,55	3,54
Toile forte	Chaîne	Chaîne	3,79	2,96
	Chaîne	Trame	3,34	3,13
	Trame	Trame	3,79	3,17
	Trame	Chaîne	3,76	3,36
	Moyenne		3,67	3,15

Tableau 5 bis

	Sens toile tableau	Sens toile de doublage	Rentoileur n° 2 Avant essai climatique	Après essai climatique
Toile légère	Chaîne	Chaîne	3,65	3,79
	Chaîne	Trame	3,31	3,08
	Trame	Trame	4,05	2,95
	Trame	Chaîne	3,82	4,18
	Moyenne		3,71	3,50
Toile forte	Chaîne	Chaîne	4,48	4,18
	Chaîne	Trame	4,41	3,75
	Trame	Trame	4,06	3,65
	Trame	Chaîne	4,86	5,08
	Moyenne		4,45	4,16

D'une manière générale, les échantillons du rentoileur n° 2 qui a utilisé moins de colle présentent l'adhérence la meilleure. Le vieillissement en enceinte climatique entraîne une légère perte d'adhésivité. En ce qui concerne l'influence d'une disposition symétrique ou antisymétrique des toiles sur l'adhérence, on constate :

Que le premier rentoileur obtient une meilleure adhérence chaque fois que les chaînes sont parallèles (résultat moins marqué après vieillissement).

Que le second rentoileur obtient une meilleure adhérence chaque fois que les chaînes sont croisées.

La disposition mutuelle des toiles semble donc avoir une influence primordiale en ce qui concerne la résistance au décollement. Néanmoins, selon les gestes et le mode de travail du rentoileur, le croisement aura des conséquences qui peuvent être opposées.

VI - CONCLUSIONS

Dans les limites expérimentales de cette étude sur l'importance des dispositions respectives des toiles support de peinture et toiles de doublage, il apparaît :

- Que la stabilité dimensionnelle des rentoilages n'est pas influencée par la disposition simétrique ou antisymétrique des toiles.
- Qu'il est important, pour la tenue au fluage, de disposer le sens trame de la toile de doublage décatie dans le sens d'application de l'effort maximal.
- Que le comportement élastique du rentoilage peut être amélioré selon une disposition symétrique des chaînes (chaînes parallèles), surtout lorsque la peinture est sur une toile forte.
- Que la résistance au décollement est très fortement influencée par la disposition de la toile de doublage : si, à cet égard, il n'est pas possible de tirer une règle générale, chaque artisan pourra exploiter cette information en fonction de sa technique propre de mise en valeur.

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Zagreb 1978

2 - R. GUILLY, M. SOTTON, M. CHEVALIER :
Etude de l'opération de décatissage des toiles de doublage en lin. Analyse comparative des caractéristiques des toiles décaties artisanalement et industriellement.
Comité ICOM pour la conservation
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3 - R. GUILLY, M. SOTTON, M. CHEVALIER :
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Comité ICOM pour la conservation
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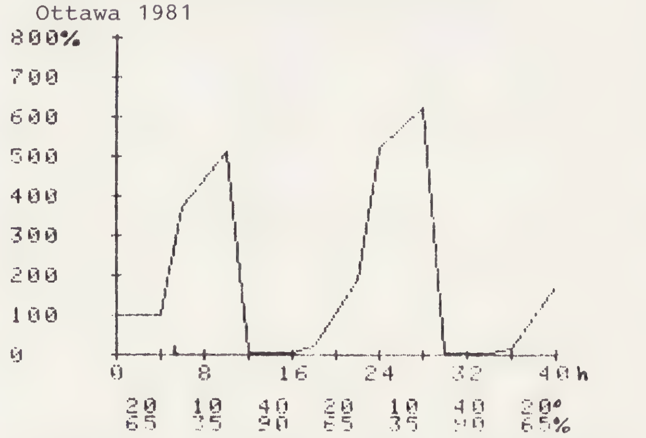

Figure 1 A - Série 1 - Toile légère TR-CH

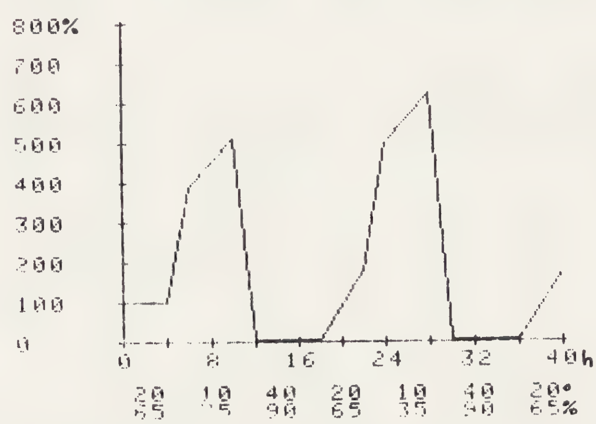

Figure 1 B - S 1 - Toile légère TR-TR

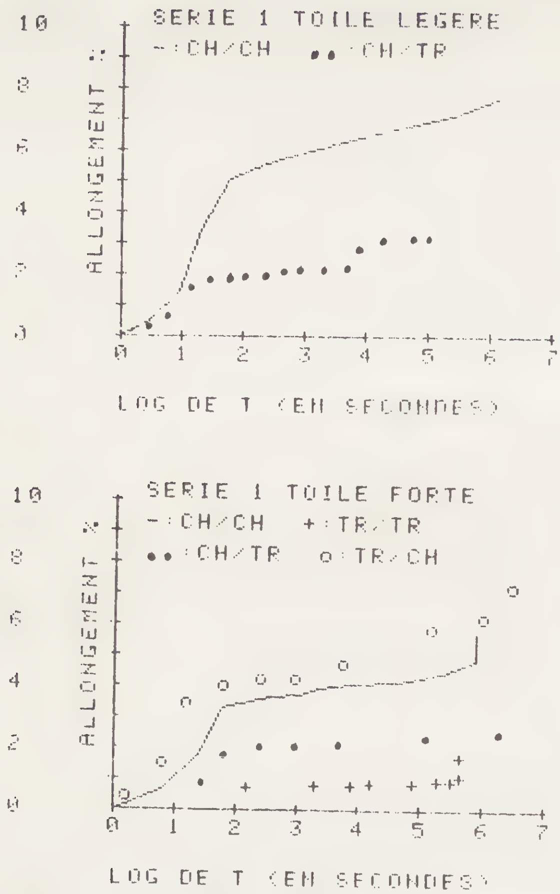

Figure 2 A

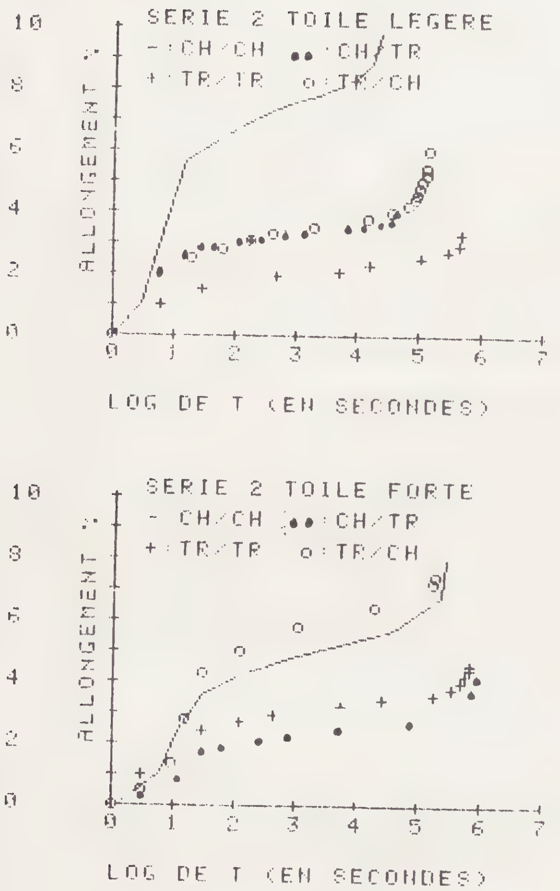

Figure 2 B

Section 3

Ethnographic Materials

Matériaux ethnographiques

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Programme 1981 - 1984:

At the 1981 Ottawa Meeting a programme was proposed in the course of a discussion with the Working Group members referring to following topics:

1.) Pest control in ethnographic museums. Effectiveness of weak or non-toxic substances in pest control; evaluation of natural products as insecticides; studies on problems arising with the use of ethylene-oxide as a fumigant.

2.) Recommendations concerning storage systems for ethnographic materials in a newly built museum. Environmental problems in storage areas for ethnographical collections.

3.) Studies on conservation and restoration of ethnographic objects made of organic materials such as bark cloth and artifacts made of bark; basketry ware; conservation and restoration of feather work; conservation of ethnographic paintings; adhesives in the restoration of ethnographic materials; consolidation of pigments as well as powdery and flaking pigments on ethnographic artifacts.

4.) Establishment of an Ethnology-Group Newsletter; literature review concerning conservation, care and storage of native tanned artifacts and ethnographical ivory objects.

Activities 1981 - 1984:

Some topics of this proposed programme could be realized, some are still under preparation. Papers will be presented on the field of pest control and storage systems in an newly built ethnographical museum. Studies were also carried out on restoration and conservation of ethnographical feather work and on artifacts made of bark. Of great importance was the establishment of the Newsletter, in the first stage planned by Thomas Stone for the Working Group Ethnographic Materials. For economic reasons, however, the Directory Board has founded a joint Newsletter for the ICOM Conservation Committee.
Finally papers will also be presented on an old traditional handicraft, the glass subsurface paintings in Romania, as well as a paper pointing out ethical considerations in the restoration of an ethnographical object.

Conservation and Restoration of Ethnographic Objects - a Brief General Statement.

Peculiarities - difficulties and problems facing us - programme and aspects for the future.

Ethnographic objects were used in the cultural life as well as for artistic and religious activities of mankind and some of them are even used today. For this reason the practice of preservation and restoration of ethnographic materials often widely differs from that existing in the conservation of other types of objects. Following circumstances are characteristic of the restoration of ethnographic materials and they often cause great difficulties in the restoration work:

1. The enormous variety and quantity of materials. Ethnographic objects can be made of all imaginable materials. They usually were made for practical use. Neither material nor quality of manufacture is intended to last for ever. Therefore ethnographic museums would need a great number of specialists in their restoration departments.

2. Ethnographic objects have many different shapes, making storage more difficult.

3. Ethnographic objects are of a complex nature. They are composed of different kinds of material and there often exist various types of implements (e.g. musicinstruments, weapons, looms ...). This fact complicates restoration treatment, because the different materials often cannot be separated for restoration purposes.

4. For an appropriate restoration knowledge of old handicraft techniques is frequently necessary. The use of original materials and traditional methods should be desired.

5. Ethnographics are sometimes even in use whilst being preserved. Beyond this special aspects are taken into account in restoring ethnographics. As a general rule, western notions of culture and style can serve only as a frame of reference in discussion of the principles governing the restoration and conservation technique of ethnographic materials.

Conclusions and rules resulting from the peculiarities and difficulties mentioned above:

1.) In smaller ethnographic museums often only a small staff, sometimes untrained and unspecialized, works in the restoration department. Commonly one, two or three persons are responsible for the restoration of all kinds of materials. Therefore it is of great importance first of all to improve the basic conservation measures. This means: establishing optimal climatic conditions in the exhibition rooms and especially in the storage areas as well as installation of appropriate storing systems and last not least precaution by efficient pest control activities.
Since 1975 the Working Group has taken up these topics in its programme. Some remarks and trends concerning the application of insecticides in the museum's pest control should be emphasized here: One should give attention to the toxicities of insecticides for human beings under consideration of the environmental problematic. Advantages and disadvantages of synthetic and natural products should be considered under this point of view while giving attention to resistence problems. Tendencies are emerging with regard to a moderate application of insecticides and trends are evident for preferences given to natural products rather than synthetic insecticides.

2.) Another point of main efforts in the Working Group programme of the last periods was set on the conservation of organic materials, typical for ethnographic objects such as those made of plant fibres: strings, cords, aprons etc. made of grasses and bast, bark cloth, objects made of bark, basketry ware; furthermore objects made of feathers and feathergarments. An improvement of conservation and restoration methods in this special field has been

encouraged in discussions with the members in the Working-Group sessions since 1975, so that studies on these kinds of materials were taken up in the Working-Group programme. The importance of special activities and great effort in this field is evident, because ethnographical conservators are right in being worried about increasing decay of these objects and their preservation for the future.
An improvement for methods to fix loose or flaking pigments on ethnographic objects made of wood or skin (shadow puppets) or from ethnographic paintings should also be worked on. Furthermore conservation and restoration of lacquer-work and ivory should be kept in especial view in future.

3.) Attention should also be given in the future to the study of old traditional and often no longer existent handicrafts in order to better carry out the conservation work on ethnographic materials. They often can give indications or advice for a restoration work e.g. in restoring damascene swords, lacquer work etc. Recently a project was started by the National Museum of Denmark to study old materials and techniques used by painters in the region of Orissa (India) for their paintings. This work should help to restore optimally a large "Puri" painting using traditional methods.

4.) Also ethical points of view should always be taken into consideration before restoration of an ethnographic object is carried out. Studies on these topics are essential for conservators in ethnographic museums. By these means and considering the former use of an object (each object has its own history!) one can avoid removing documentary patinas, decorations, different applications, believing this to be so-called "dirt". Under these aspects a restoration of an ethnographic object has to be done with open eyes and restrictive so far as possible, preserving its documentary value: often conserving and preserving has priority over restoring.

Acknowledgements:

The Working Group is endeavoured to observe all the above mentioned problems. But I emphasize that the Working Group also lives from the activities of its members. Therefore I ask you earnestly to participate in the Working Group programme according to your abilities. My great and special gratitude is due to all authors who will present papers for the Copenhagen Meeting, who have devoted time and pain to preparing their contributions. In this connection I am also very grateful for all work which was done in the last three years to support the programme of the Working Group.
I am very grateful to all members, who are still working on conservation problems. I thank for your cooperation and for useful information. Finally I wish to give my very special thanks to the efforts of ICOM and ICCROM who support the activities of the Working Group.

GLASS SUB-SURFACE PAINTING IN ROMANIA, SEVENTEENTH TO TWENTIETH CENTURIES

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SUMMARY

Through interpretation of Western technical sources of the sixteenth and seventeenth centuries and of local data, the technique of Romanian glass sub-surface painting is described. This information confirms the idea of a traditional technique adapted to the needs and resources of the Romanian countrymen.

The term glass sub-surface painting describes icons painted in Transilvania since the seventeenth century, northern Oltenia and Muntenia, and northern Moldova since the eighteenth century.

The term glass sub-surface painting properly describes a craft popular in Romania from the seventeenth century and characterized by being painted on the back of a piece of glass, further fastened to a backing and a wooden frame. It refers to icons painted in the province of Transilvania since the seventeenth century, northern Oltenia and Muntenia, and northern Moldova since the eighteenth century. It has been suggested that this craft, presumed to be Byzantine, originated in Western and Central Europe, where in fact it is widely practised, and has been brought by settlers, together with the collections of prints used as models for these icons. The models (izvoade) were copied on paper, which was annointed with petroleum in order to render it transparent (a form of tracing paper.) The drawing was transfered to glass by coloring its back with charcoal.

Artists' color powder or pigments were available to the countrymen through several sources. They came through local shops and peddlers and were locally mined. The colors were home mixed with a binder. Also important was glass, which was made locally.

It is hoped that through a study of Western technical sources of the sixteenth and seventeenth centuries the technique of Romanian glass sub-surface painting will be elucidated (1).

The Marciana MS specifies:

"If you wish to paint with other colors which... remain on the surface, especially with verdigris, fine lake, peach or charcoal black, and all colors which have no body [i.e. are transparent] and also fine blue... give a coat of walnut, or linseed oil, which is to be preferred on glass, let dry in the shade, then grind the color with the same oil, paint upon the coat of oil and let dry... you may even varnish it afterwards... If you want to paint on glass a putrido. Lay on a coat of hot glue, and when this is dry paint on it. You may temper the colors with yolk of egg, and also with weak and slightly warm glue, the blue and the white especially...."

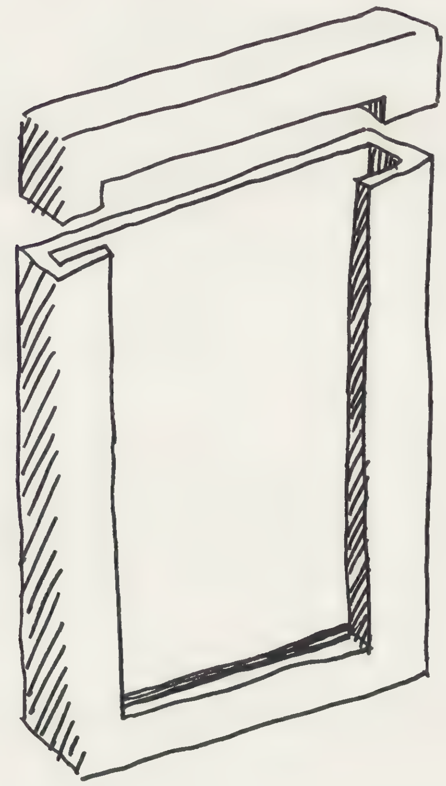

Figure 1 Icon frame (after J.Dancu et. al., p. 103)

The Paduan MS recommends:

"First grind the colors with boiled oil prepared in this manner: take half lb. of litharge and one lb. of walnut oil, grind the litharge and put the whole into a glazed earthen vessel and boil until the oil is reduced by one third. It serves for painting on glass."

Figure 2 Wood knife, used for collecting the color paste off the slab (after J. Dancu et. al., p. 57)

A varnish is described by the Marciana MS:

"Take Venice Turpentine,... if you wish to varnish permanently... do not thin it with

other ingredients, but heat it in a vessel, and varnish with it."

For further information on the technique of Romanian craftsmen we turned to Cornel Irimie and Marcela Focsa (2). The painter (zugrav) lays first the preliminary outline: he uses black pigment ground with alcohol and further with glue and yolk. He next lays the writing. The painter applies then the light accents and the local colors. Pigments are mainly ground in oil. Turpentine spirit and lead acetate are mixed in to the paste while coloring. Corrections and retouches are not possible. When this is dry, a final oleoresinous layer may be applied. The final gold or silver foil, usually a bronze or tin foil, serves also as an overall background (3).

These informations confirm the idea of a traditional technique adapted to the needs and resources of the Romanian peasant. The execution was somewhat difficult. The painter had to keep in mind that the final composition will appear and must be viewed in reverse; this is why these icons are sometimes also called reverse paintings on glass.

References and footnotes

1 M.P.Merrifield, Original Treatises, etc. (New York: Dover, 1967), p. 617 and 635 (Marciana MS of the sixteenth century) and p. 693 (Paduan MS of the sixteenth or early seventeenth centuries.)
Litharge, i.e. yellow monoxide of lead, is extensively employed as a drier in paints. Oleoresin is a natural combination of resinous substances and essential oils exuding from plants; Venice Turpentine, a soft semi-liquid, is part of the turpentine group, derived from Coniferae. For a detailed historical study of Romanian glass sub-surface painting see J.Dancu, D.Dancu, Die bauerliche Hinterglassmalerei in Rumanien (Bukarest: Meridiane, 1975).

2 C.Irimie and M.Focsa, Icoane pe sticla (Bucuresti: Meridiane, 1971), p. 21. Lead acetate is a metallic salt added to oils for the purpose of accelerating the rate of drying.

3 It is worth mentioning that, as this craft is still practised in today Romania, first-hand information could be obtained on peculiar techniques and mediums developed in various areas. Thus, besides the usual medium based on linseed oil (called varnish, presumably a heat-treated oil) and lead acetate, a tempera emulsion was also sparingly used. For example, in the village of Nicula, an emulsion of glue-size, varnish (linseed oil) and possibly some coach-varnish (based on an oil-modified copal resin) replaced the oil medium. In the village of Laz, a tempera emulsion made of linseed oil varnish and glue-size was currently employed. See J.Dancu et. al., for more details.

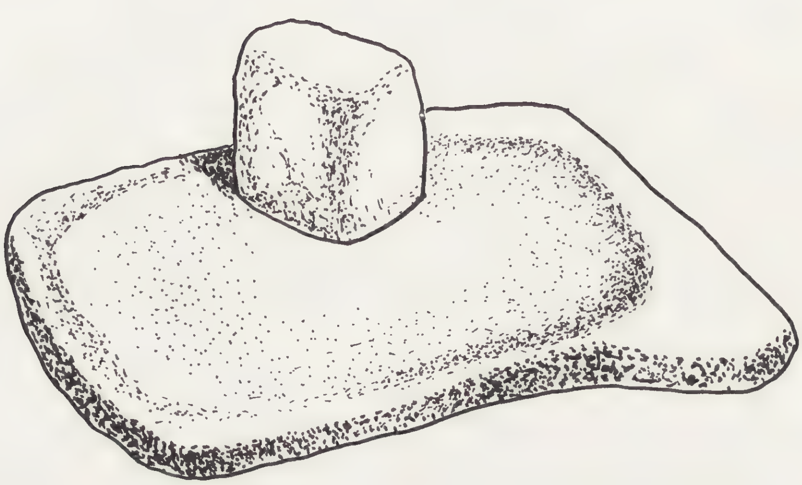

Figure 3 Stone slab and muller -- called lufăr after the German Läufer -- used by five generations of the family Poienaru (after J.Dancu et.al., p. 123)

STORAGE AT THE NEW ETHNOGRAPHICAL MUSEUM IN STOCKHOLM

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SUMMARY

Since 1978, the Ethnographical Museum in Stockholm has been housed in a completely new building in which the facilities include new storage premises for the roughly 150,000 objects for which the museum is responsible.

In the old museum, the objects belonging to the collections were very poorly stored, heterogenously distributed and in such condition that a total inventory of the entire stock of objects was essential.

Storage in the new premises was planned to be classified on the basis of groups of material and based on climate zones to create optimal storage conditions for each individual object. The limited storage volume available also made it necessary to classify the objects in each material group into size groups to ensure that the storage premises would be utilized as efficiently as possible.

The museum is divided into five different climate zones. In the exhibit halls and main storage we have a common background climate. In addition, we have special climates for lacquer work, bronzes, textiles and furs. The utmost importance has been attached to the attainment of storage systems satisfying the stipulated requirements of flexibility and simplicity, and made of material that does not damage or affect the objects.

The storage system are also designed with due allowance to the needs of the fire fighting authorities, cleaning and pest control.

The Ethnographical Museum in Stockholm was previously housed in the old and dilapidated barracks that have previously belonged to a regiment of cavalry located in the eastern outskirts of Stockholm.

At that time the museum was divided into a number of separate buildings housing exhibit areas, storage, general office and workshops. These buildings were not contiguous and lacked permanent undercover passage connections. This posed problems when transporting material from building to building. The old premises were seriously dilapidated, impractical and far too small. In particular the storage area was totally unsuited for the close on 150 000 objects. These were distributed throughout a number of small rooms and stored according to the collection to which they belonged.

Due to the lack of available storage space, many objects were still packed in the crates used when the museum moved house in the 1930s.

Objects that had been unpacked were exposed to dirt and dust on shelves, benches and the floor, in many cases piled on top of one another.

This state of affairs was instrumental in initiating a discussion on the construction of a new building towards the end of the 1960s.

In the full flush of the economic boom in Sweden at the beginning of the 1970s, a decision was taken to build a completely new Ethnographical Museum. In the wake of an architectural competition, the National Swedish Board of Public Building decided to build a new museum under its own auspices. Construction work on the new museum to be built on the site of the old one, was scheduled to commence in 1976. One of the main features of the new museum was to be the provision of modern, up-to-date storage premises of sufficient size to house all the museum's existing objects and future acquisitions. This would ensure that the museum would be able to preserve and look after its collections in a satisfactory manner.

Because construction plans called for the new museum to be built on the site of the old one, we had to crate all our objects and move them to temporary storage premises in anticipation of the completion of the new museum. In August of 1975 the work of crating the collections began and was completed by the beginning of January 1976 when demolition work on the old museum was scheduled to commence.

The work of crating the museum objects took longer than we anticipated and the five months that were available for the completion of the work were barely sufficient. The process of packing objects involved wrapping them in acid-free tissue before packing them into crates of varying size filled mostly with wood shavings. A rough classification of objects by type of material was made during the crating process. This entailed packing and moving objects in groups classified by material; this is the fundamental principle we use for storing objects in the new museum.

Particularly heavy or fragile objects were packed and transported separately.

Throughout the 1976-1978 period, when construction work was proceeding on the new museum, we had time to plan the new storage area, design and test new storage systems and to establish the routines and procedures for handling objects and vouchsafing their care and safety. We now had an excellent opportunity of recommencing from scratch in the new museum with the introduction of new procedures and the modification of those that had proved unsuitable in the past.

Throughout the construction period we had, in addition to the opportunities outlined above, sufficient time at our disposal to prepare many objects for the move to the new storage area by conducting an object inventory on the basis of the new storage classification principles. The time available while the new museum was under construction enabled us to take inventory of about 50% of the non-textile objects. For this purpose, we compiled special lists on which objects were itemized, measured and classified by material, size and climatic environment.

We have an interim station in the new store for objects excluded from the inventory and classification by material size and other criteria because of lack of available time. This interim station is now used to classify these objects before they are ultimately consigned to the storage area.

All objects are classified into one of the main material categories and sub-divided by size before entering the storage area.

The climatic storage environment is determined on the basis of the component materials of the object, to ensure optimum environmental conditions for each individual object. Objects in the old museum were stored on the basis of the collection to which they belonged.

Three separate climate zones are currently used for non-textile materials. In the exhibit areas and the main storage area we attempt to control the background climate at a relative humidity of 45-50% and a temperature of 18-20 °C. In addition, we have a storage area with a higher relative humidity of 60%; this is mostly used for the storage of Japanese and Chinese lacquer work. We also have a storage area in which relative humidity is held below a maximum of 40% where we store our bronze objects.

Two separate sections of the storage area have been set aside for textile material, each with their own controlled climate. The museum's furs will be stored in a refrigerated area. All in all we have facilities for storing objects in five different controlled environments.

In each material classification group, objects are stored by size to optimize the use of existing storage space. We make every effort to ensure that objects are grouped by type and region as far as possible in each material classification and size category. Overall storage area is about 3 000 m^2 (32.300 ft^2) for the 150 000 or so objects currently owned by the museum.

We have also developed special procedures for unpacking and cleaning objects before they are consigned to the storage area. Objects are unpacked on special premises carefully separated from the storage area. After objects have been removed from the crates, all packaging material, including wood shavings and tissue paper, is carefully checked before it is discarded. Compressed air is used to clean (dust off) the surface of objects. The purpose of this blow cleaning is to remove the loose surface dust to ensure that we maintain as clean and dust-free an environment as possible in the storage area. Our cleaning staff perform regular cleaning of the floors in the storage.

Objects are also carefully checked at this stage for signs of damage by insects. All objects with visible signs of damage caused by insects are fumigated and a record is compiled of all objects so treated. The fumigation was performed in the old storage area immediately before the move and all new objects of organic composition are fumigated. The museum has signed a contract with a pest control company for the performance of this work, which is done with methyl bromide or prussic (hydrocyanic-) acid. Equipment for using ethylene oxide is available in Gothenburg and Malmö but not, as yet, in Stockholm. It will be readily understood that these elaborate procedures have been adopted to ensure that the storage area is kept free of insects.

As an additional safeguard, the fixtures and fittings in the storage area have been designed to provide technical capability for performing a fumigation of the storage area in the event that the unthinkable should happen. Objects are also carefully checked to ensure that they are properly and thoroughly marked. Unmarked objects have been collected in a special area in the storage, where our researchers can work on their identification. Only when the objects have been marked can they be permanently stored.

In most cases the identification mark is applied directly on the object. In many cases this marking is supplemented by an additional, temporary storage identification, somewhat larger in size to facilitate identification and to minimize physical handling of objects.

We have adopted two completely new storage systems for the storage area. One for textile material and one for other types of material (non-textile), such as wood, leather, metal, ceramic, stone, basketry, ivory, etc.

These systems were developed in close cooperation between museum staff and interior designers. The object of this exercise was to develop a system that would prove simple, efficient, flexible and capable of safeguarding objects. We elected to adopt an enclosed (in contrast to open) storage method, rather than a moving, stacking system in favour of a permanent system to avoid jeopardizing objects through excessive wear and tear and vibrations.

For non-textile material, we used cabinets consisting of a metal, electroplated metal frame with fittings of untreated birchwood. The shelves consist of laminated pine veneered and edged with birchwood. The dimensions of our 900 cabinets are as follows: height = 230 cm, width = 120 cm, depth = 60 cm. These cabinets are in most cases arranged in double rows and fitted with glazed doors to enable objects to be inspected without opening the cabinets. This is a very useful feature on the numerous occasions when objects are inspected directly and selected for exhibitions. The cabinets are designed and built to admit as little dust as possible while maintaining sufficient ventilation to prevent the formation of a microclimate inside the cabinet.

The wood fittings in the cabinets have been deliberately left untreated because of the characteristic buffer action of natural wood in compensating fluctuations in relative humidity.

This a valuable quality in the event of an uncontrolled shutdown of the climate control system.

The interior fittings of the cabinets can be rearranged to reflect the size of the objects they contain.

The interior fittings consist of sliding shelves that can be withdrawn to improve accessibility. In some cases, shelves are permanently fixed in position, as sliding shelves are unsuitable for some types of

object. The distance between shelves can be adjusted to suit requirements. The rear and side walls of the cabinets may be rearranged to separate one unit from another. To accommodate large objects, several cabinets can be used together with all their shelves removed. All cabinets feature a top and bottom to provide fully enclosed units. Very large and heavy objects are stored on pallets in a standard industrial pallet rack.

For small objects we have developed a system of cardboard boxes in four standard sizes, adapted to fit into the shelves. These boxes are made of white, fine corrugated board. This is a bleached paperboard material with a pH of 6.3. For extra protection, all objects are wrapped in acid-free tissue before insertion in the boxes.

We only use incandescent lighting for illumination purposes in the storage area as this type of bulb generates less harmful radiation than the fluorescent tube. No direct sunlight enters the storage. Because storage cabinet doors are glazed, it is vitally important that we exercise strict lighting discipline to ensure that objects are exposed to as little light as possible.

The storage areas are divided into sections separated by 210 cm wide gangways. In each section, storage cabinets are arranged in double rows separated by an 85 cm wide gangway. There is only one light fixture per gangway in the narrow gangways in the sections. This fixture is suspended on a wire and can be moved along the entire length of the gangway. The light may be raised or lowered to the desired level and is suspended on a counterbalance device to ensure that it remains in the desired position.

These lights are switched on and off individually with a switch located at each end of the gangway. The wide gangways dividing separate sections of the storage area feature several fixed light fixtures. Switches located at each end of the gangways are used to switch the lights on and off individually.

A central switchboard unit is located at the main entrance to the storage area to control the entire illumination system in the storage area. This control panel has master switches and annunciators, enabling staff to quickly review the situation and switch off the lights when they are not needed. We have adopted this system to ensure that objects are exposed to a minimum amount of light and that light is only available when and where it is needed. At all other times, the area should be kept as dark as possible. It is important to remember that such a system depends in practice on readily accessible, strategically sited switches.

To clean the air in the museum, the ventilation system is equipped with mechanical filters through which the air is recycled twice in every sixty minute period. This system will trap 100% of particles in the air down to a size of 2.5 µm. No chemical air filters are considered necessary as the museum is located on the outskirts of the city of Stockholm. Nevertheless, the ventilation system is prepared for the addition of this type of filter should this prove necessary in the future. Inspection, maintenance and calibration of the ventilation system is conducted on a regular basis by the museum janitor to ensure optimum function.

Ten recording thermohygrographs are used to monitor the climate in the storage and exhibition areas at monthly intervals. The charts recorded by the instruments are compiled every twelve months to check maximum, minimum and mean values, as well as the amplitude for each measuring station and year.

As pointed out elsewhere, the storage area is divided into separate sections. Objects are allotted a permanent place in the storage area after classification by material, size, type and region. The object position code is based on a logical, topographical structure ranging from section down to a uniquely specified shelf section. The position code of a given object will state the section, cabinet row, cabinet, shelf and shelf position in which the object is located.

Each shelf (114 x 55 cm) is divided into 24 rectangles (6 x 4) measuring 13 x 18 cm. This surface area is the smallest (and most accurate) store location that our system permits us to assign to an object. Our four standard size cardboard boxes are modules of this system and the smallest covers the same surface area as one square. The next box on the size scale covers a module of two squares, the next size a surface area of four squares and the largest box covers an area module of eight squares.

This system enables us to combine boxes of different size. Box height is 10 cm, except for the largest unit which has a height of 20 cm. These boxes do not have lids. Boxes are marked with their store load position and their size. Marking the module size on the box is very useful when withdrawing a box. The module size indicates the length of the box. This is not always visible from the outside when the shelves are packed close together. All that is visible is the shortest end of the rectangular box, and this is identical for three size modules.

The store position code and the object number are recorded and processed in a computer to generate store location and inventory lists. Each cabinet contains inventory lists. When an object is withdrawn from the storage area, its storage location is physically marked. This simplifies the task of replacing the object and prevents any other object from being placed in the same position.

Admission to the museum storage area is restricted only to conservators and museum technicians whose work is directly involved with the operation of the storage area. Researchers at the museum do not enjoy unrestricted access to the storage area. This rule is essential when responsibility for the care and organisation of objects is vested in the conservators and museum technicians.

The installation of a sophisticated alarm system vouchsafes the security of the storage area.

A water sprinkler system has been installed throughout the entire museum to afford protection against fire. In the storage area, the sprinkler system is a dry system: such a system will not normally contain any water (if not activated).

The storage area sprinkler system will be activated and filled with water in about 20 seconds after any of our smoke detectors have triggered the fire alarm. This system provides a safeguard against inadvertent triggering of the sprinkler system.

It has given me great satisfaction as conservator and trustee of the objects to have been given the opportunity to participate in the building up of a storage of this kind.

This storage with is resources affords us with ample possibilities of taking care of and preserving our collections for future generations in a satisfactory and damage-preventing manner.

This, however, has only become possible thanks to the complete understanding of the museum management and of the responsible decision makers who made the necessary funds available to us.

It is now my sincere hope that our experience and the principles drawn up by us for the storage of objects will prove beneficial to other museums.

MAORI CARVINGS IN AUCKLAND MUSEUM, NEW ZEALAND. ETHICAL CONSIDERATIONS IN THEIR RESTORATION.

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SUMMARY

Recent conservation and restoration work on Maori wood sculpture has graphically shown the variety of surface finishes with which the artist's completed their carvings. However, up until 1953 the Auckland Museum has overpainted the majority of its carvings with matt red paint, obliterating earlier polychrome and unpainted surfaces. This paper discusses the reasons for this overpainting and the new Museum policy for the display of Maori carvings resulting from the conservation work so far completed.

New Zealand Maori wood sculpture is more often than not painted in various tones of red paint. For example at Auckland Museum, the major ethnographic museum in New Zealand, 75% of the house and monumental carvings on display are coloured with a heavily pigmented flat red enamel. Looking at such a collection the immediate assumption is that one is seeing Maori carving in its traditional form - that, with a few exceptions the Maori artists of the 19th century and by implication earlier centuries also, coloured their carvings red. The importance of red as a colour is well known, representing as it does in New Zealand and Polynesia generally, the power of the gods and of mana, a term broadly translated as spiritual and personal prestige. The carvings being coloured red are, therefore, of great spiritual importance.

However, conservation work over the past two years on a number of large carvings has revealed that the carvings were in fact not red when they first entered the Museum but were overpainted as they were accessioned into the collection. The Pukeroa Gateway from Rotorua was originally polychrome before being painted in the early 1890's and again in 1953. A ridgepole from a meeting house in the Bay of Plenty was uncoloured until it arrived in the Museum in 1918, while from another meeting house at Okere Falls near Rotorua the maihi or bargeboards were partially painted at the museum sometime after 1935 and the carved finial or tekoteko had its original bare wood and black paint details overpainted red and black. The Auckland Museum meeting house was polychrome until it was placed in the Museum in the late 1920's where upon it was coloured matt red with some black paint highlights. The conservation work has led to a re-assessment of the red paint on the carvings and initiated a search into how such a thing could have happened in the first place.

The general opinion on how the carvings became painted red is that the first curators of the collection assumed that accounts in the ethnographic record of red coloured carvings also applied to the carvings in their collection, those that were not already red should be, and consequently were, promptly rendered so. Apart from museum oral history there is nothing to substantiate this opinion. Nevertheless it seems the most feasible reason for the painting as it is hard to believe that the curators from the late 19th century to the 1950's would have willfully pigmented non-coloured or polychrome coloured carvings red.

The story of basing the colouring on ethnographic accounts rings true enough particularly when one considers the educated British colonist's view of Maori Society at the end of the 19th century, when the first carvings were over-painted at Auckland Museum. From their point of view it seemed the Maori people were facing inevitable extinction, therefore their material culture had to be preserved before the last of its makers passed into history. In an effort to "get the story right", it is easy to imagine the almost contemporary polychrome carvings being dismissed as a recent aberration of decultured natives and being over-painted red in imitation of the "traditional" kokowai or red ochre. From that standpoint it is but a short step to paint uncoloured carvings red as well. Myth compounds misunderstanding; half remembered recollections of "the Maori as he was" measured against the presence of the Maori of the late 19th century; that feeling that the old time Maori cut a far finer figure than his grandchildren, could all add up to a viewpoint that Maori art and culture had to be presented in a time slot when little had been affected by European presence. In the case of wood sculpture, pieces that didn't conform to an idealised image of the past could be made to by painting red in imitation of kokowai.

Assuming that this is a more or less correct version of the events leading to the painting of the carvings, what was the pre-European appearance of house and monument sculpture? Were they coloured red? If so, was it a New Zealand wide style of decoration. Looking at ethnographic accounts from the pre-1830 period of European settlement of New Zealand we have a number of journals, mainly from explorers and missionaries. These accounts relate to specific geographic places located in the upper third of the North Island of New Zealand. That red ochre was abundant is apparent from the numerous references to its use as a cosmetic, but in house carvings, monumental carvings, it seems to have been used rarely as decoration. The carvings mentioned appear to stand out as exceptional rather than simply the best examples of the carver's skills. They also appear only in the Bay of Islands area, even though the writers of the time travelled extensively about the North Island. Given the wealth of detail in the various journals we can only conclude that, rather than red coloured carvings being so common that they don't rate mentioning, the true situation is that there were none to record apart from a small number in the Bay of Islands.

With post-1830 accounts and especially post-1840 accounts when the interior of the country was being systematically

explored by British colonists, a different picture emerges. They comment on red-coloured carvings from all parts of the North Island south of Lake Taupo so it would seem that such colouring was an established tradition for much of the southern portion of the country with perhaps special emphasis on the use of kokowai in the inland area about Lake Taupo. A statement made by the missionary Colenso in 1881 would probably stand for these regions. "They used this colour ... only extensively and commonly for their war canoes, their chiefs' private and their village big reception-houses, their kumara storehouses and the large carved images on the outer fences of their pas (towns and forts), for their grave fences and monuments, and for their boundary and other raised cut commemoration posts: all of which were more or less public and superior matters."

Looking at material evidence we refer to the Auckland Museum's collection of carvings. Only 15 carvings on public display show original surface finishes, and of these two show signs of red ochre having been applied to them. They are carved burial chests from Northland. It could be argued that the red ochre had weathered off the surface long before they were collected by the museum which is a possibility but the fact remains that the majority of the carvings in the uncoloured category were excavated from swamp locations where the ochre paint would have been preserved. There is a precedent for this, with the discovery in the 1960's of a large cache of ornamental combs covered in red ochre in a swamp, the oldest of which dates back 400 years. Perhaps it should be mentioned at this point that there are other pieces of carving on display which have red ochre smeared and painted on them but these are much smaller items such as god sticks and personal items such as small intricately patterned boxes. Interesting as they are as artefacts they are outside the scope of this discussion.

The unpainted carvings in storage at the Auckland Museum also show no signs of having been painted with red ochre in the past. Three important swamp finds of carvings in 1979 and 1981 from Waikato, Hauraki and Coromandel had no colouring on them whatsoever endorsing the appearance of the other swamp discoveries found earlier in the 20th century.

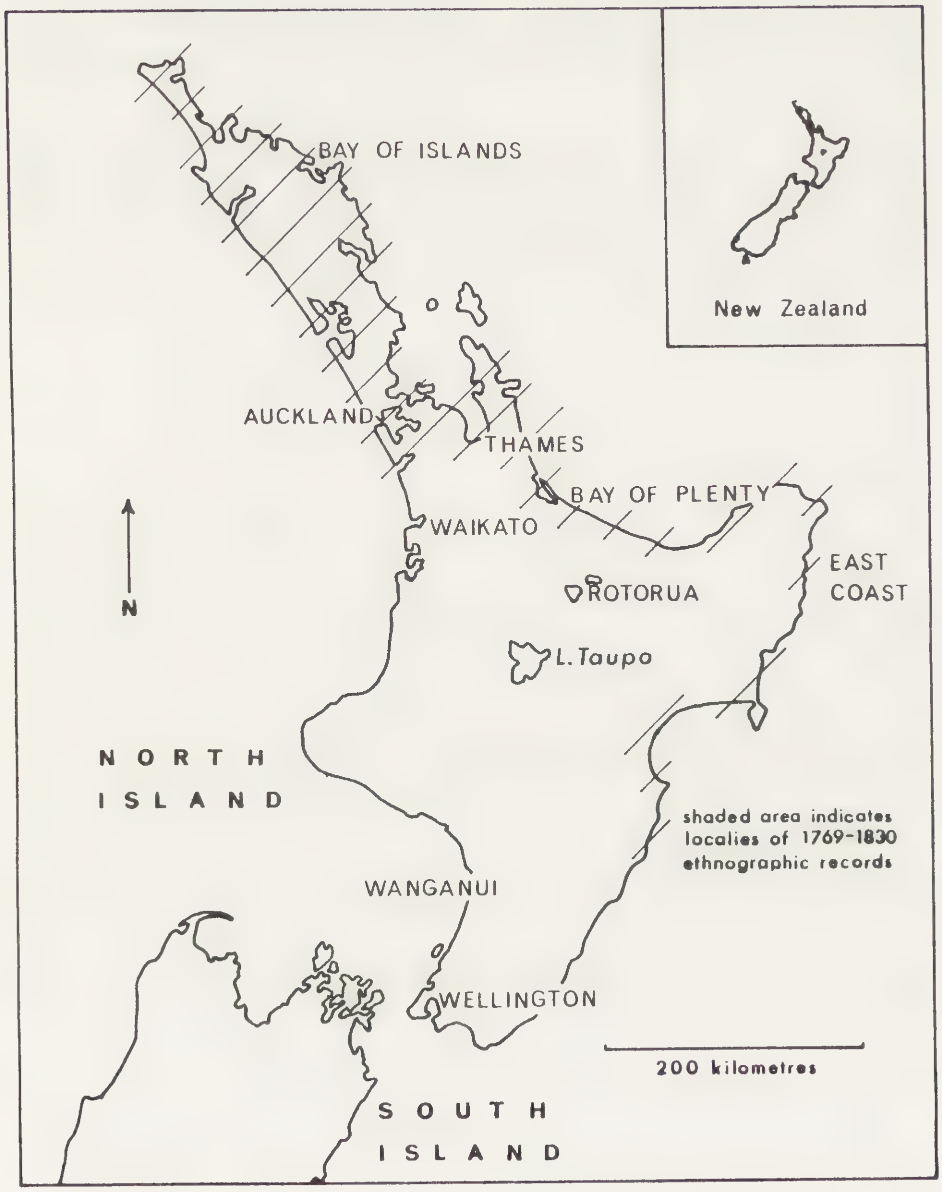
What one does see in the collection in storage however, are carved pieces dating from the mid 19th century, which have been painted with European paints of various colours and it is their counterparts on display which have been extensively over-painted with red paint by the museums of the country. In effect, museums have obliterated, from a public display point of view, a whole style of decorating carvings which spanned more than 60 years.

Paint of European origin seems to have been used from about the 1860's. Various colours were selected, black, green, red, white, pink and orange can be seen in various juxtapositions on a number of carvings in storage and on restored pieces. Photographs of the period show house after house with carvings obviously decorated with several contrasting colours. From photographs there is no indication that red as the sole colour for decoration was preferred to a polychrome appearance and it seems that as soon as a wider palette was available it was used. The newly accessible paints were applied in ways that not only added new colour to the carvings but were also being used to enhance the details in effect creating optical illusions where it was felt such a trick would increase the carving's impact. An example of this is the artificial shadow added to the contours of the Pukeroa Gateway by way of outlining sections of the work with black paint.

The use of European paints was widespread across the North Island and according to David Simmons, ethnographer at Auckland Museum, some regional variation can be seen in colour combinations. In the East Coast region the pre-European choice of black and red was carried through into the 20th century; further west in the Bay of Plenty region the traditional Polynesian tricolour of red, white and black appeared as it also did on the west coast about the Wanganui River. The Waikato-central North Island region, saw pinks, reds and oranges used with creams and white, and restrained use of blues and greens. (See map for location of regions.) Parts of this socially complex area had colour selection influenced by the colour symbolism of the Ringatau religion which established itself in parts of the North Island from the 1860's onward, namely yellow, white, and the Ringatau prophet Te Kooti's personal colour, green.

Looking at archival and published material work on the history of North Island carved meeting houses, one is struck by the number of multi-coloured carvings. However, the Auckland Museum displays reflected none of this artistry until recent conser-vation work was undertaken on selected pieces. Similarly there is little or no evidence of coloured house carvings in other museums or even on the houses which are still standing in various parts of the country. The style for re-decorating house carvings in only red paint has spread far indeed and it appears that museums cannot be regarded as uninfluential in this fashion becoming as ubiquitous as it is today. The case can be put that the red colouring on museum carvings has inspired Maori communities to imitate what New Zealand museums have established as the correct way to display carvings.

Since 1982 Auckland Museum has embarked on a conservation programme to restore its carvings back to the appearance they possessed prior to becoming part of the Museum collection. The red paint currently colouring the carvings renders them lifeless and uninspiring as well as being completely misleading as to the true nature of Maori artistry. The project promises to have wide ranging effect on other New Zealand museum displays and on people's appreciation of Maori carving generally.



New Zealand
BAY OF ISLANDS
AUCKLAND
THAMES
BAY OF PLENTY
WAIKATO
EAST
COAST
ROTORUA
L. Taupo
N
NORTH
ISLAND
shaded area indicates
localies of 1769-1830
ethnographic records
WANGANUI
WELLINGTON
200 kilometres
SOUTH
ISLAND

THE CHATHAM ISLAND DENDROGLYPHS - CONSERVATION AND SURVIVAL

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SUMMARY

Concern about the survival of Moriori dendroglyphs has been expressed by various ethnologists over the past decade mainly over the examples still in situ in Karaka or Kopi groves in the Chatham islands.

Very recent concern has also been expressed on the state of the few dendroglyphs held in some New Zealand Museums. The conservation and the survival of the dendroglyphs in the Museums and in the bush are being discussed.

Introduction

The Chatham Islands are situated some 970km South East off New Zealand in the South Pacific Ocean.

The first inhabitants of the Chathams were from East Polynesian stock and arrived some 700 years ago either from their Polynesian homeland or via New Zealand. These people were later called Moriori, reduplicated from the word Maori.

The Chatham Islanders lived undisturbed until 1791 when Lt. Broughton of HMS Chatham discovered the island group.

Whalers and sealers subsequently visited the islands until in 1835 a group of New Zealand Maoris invaded the Chathams and conquered the Moriori people. The Moriori became enslaved, were totally dominated and driven from their established occupation grounds.

As an enslaved people they started to lose their will for living and began to decline rapidly. At the time of their discovery it was estimated that some 2,000 Morioris lived in the Chathams, in 1933 the last Moriori died in New Zealand.

Thus all that remains of the Moriori culture is those artefacts held in Museums and private collections as well as the dendroglyphs and petroglyphs still in the karaka groves and limestone outcrops at the Chatham Islands.

In the kopi or karaka groves many dendroglyphs are still surviving although their numbers have been declining rapidly.

Early reports giving evidence of areas which had carved kopi trees are now totally devoid of trees, areas where extensive surveys had been carried out in 1963-4, were totally gone in later surveys in 1976. The main causes for the disappearance of the dendroglyphs is bush clearance for farming and farm animals who eat the undergrowth and expose the tree roots which will then dry out causing the trees to die.

The Lands & Survey Department, New Zealand Historic Places Trust and private owners have recently fenced off a portion of the largest kopi grove and as a result rapid regeneration is taking place of the undergrowth, and trees which were lying dormant for years started to sprout new shoots. It is hoped that these protective measures will continue to be put into force so that the remaining bush and dendroglyphs will survive for future generations.

Dendroglyphs

The bark carving or dendroglyph, the term dendroglyph is arrived from the ancient Greek language dendro - a tree, glyph - a carving, are carved into the bark of the kopi or karaka tree (copynocarpus laevigata) a native tree of New Zealand and the Chatham Islands. It belongs to the hardwood, Angiosperm family, and can grow up to 18 metres high and have a diameter of up to 60 cms. Its bark is thick and soft having a corky appearance, that lends itself very well for carving.

Various opinions do suggest that the carvings represent, or are associated with, ancestors and mythology.

A recorded incident in the first half of the 19th century supports these theories. 'Menui went to the bush after the death of his wife and child and carved two figures into a kopi tree, presumably in remembrance.'

The anthropormorphic and zoomorphic figures present in the groves together with the ancestral figures do suggest that they are part of the same theories. It is accepted that most of the glyphs were carved in prehistoric or early historic times and very few were carved in recent times. This means that they are at least some 160 years old and of Moriori origin.

Methodology of the carvings

Various techniques of carving the dendroglyphs can be observed:

(a) the most simple one is the straight incision with a depth of 8mm up to 16mm.

(b) the so called 'cameo' technique, in this technique the carver carved the bark away up to the sapwood. The figure stands out in high relief as the remaining bark thickens as it heals.

(c) the etching or sgrafitto method, the figure is carved and the carved area between the incisions scraped away and stained, the figure then stands out as a dark brown-black image against the lighter background of the bark. The carver probably used either a charcoal or the peat soil for a stain.

(d) this is the reverse of c, here the carver scraped or etched the surrounding bark away from the figure and then stained it by the same method leaving the carving to stand out against a dark background.

(e) this could be a combination of either a, b, c and d.

The Conservation Problem

There are only few dendroglyphs held in Museums, Otago Museum holds 18 examples mainly collected during the 1963-4 expedition. Canterbury Museum holds 3 as does the National Museum. Auckland holds 5 examples. The British Museum has 11 dendroglyphs in its custody. No others are held in major Museums in Europe, U.S.A. or Australia as far as we know.

The dendroglyphs discussed here are those of the Otago Museum and Auckland Museum. the collection of the Otago Museum resembles closely the same problems as those of Auckland.

The dendroglyphs were removed by saw and axe and when removed from the trees left to dry out. No control was carried out over this drying out. Of the most recent collected glyphs in 1963-4 uncontrolled shrinkage took place within 3 weeks and all the examples I have examined, 23 in total, have the same deterioration.

The bark layer, the phloem, has shrunk away with a total different rate of shrinkage from the wood, has cracked, and in some cases curled inwards and become detached from the wood. In other dendroglyphs this shrinkage is not so pronounced and the bark is straight but is just detached from the wood. All dendroglyphs have the same damaged surface, where the outer thin bark layer is becoming detached from the main bark layer leaving 'blisters' which easily break, exposing the different coloured inner bark. Where this happens on a carved surface the image is altered and sometimes distorts the dendroglyph.

In the worst cases the wood has cracked, also due to this uncontrolled drying and damages the dendroglyph, in some cases beyond repair.

The problem is thus, firstly, that the blistered areas needed to be consolidated in order to restore the carved image and secondly, to consolidate the whole bark layer and the wood on which the bark lies.

Much thought was given on how to "glue" the 'blisters' and the bark back to the wood with the various synthetic glues and consolidants available. It was suggested to remove the bark totally from the wood and construct a polystyrene trunk on which to attach the bark. This was rejected out of hand as in one or two cases the bark probably could have been removed without damaging the bark and dendroglyph any further, in the rest of the dendroglyphs it would have caused considerably more damage.

After discussions with fine arts conservation colleagues it was decided to follow the procedure of attachment with waxes. Reason for this was that a flexible wax could be made using the same mixture as used in the conservation of waterlogged wood n.m.that of beeswax, parrafin, damnar resin and carnauba wax. This wax is flexible when set and has a very good adhesive quality. It sets quickly and is reversible, properties which made it far more attractive than the synthetic consolidants. Tests were carried out on a dendroglyph which were favourable and the technique was proceeded with.

The dendroglyphs were first cleaned using Lissapol NBD 2% solution v/v. in deionized water, which rinsed off at least 3 to 4 times with a soft sable hair brush making sure that the bark did not get too wet. This cleaning took usually a couple of days after which the dendroglyph was left to dry completely. The wax technique was then used with success.

In the case of the Auckland dendroglyphs, fragments of bark had been broken off over the 78 years that they have been in the custody of the Museum.

Photographic records do exist of some of the glyphs which were used when missing parts were made up using a mixture of Polyvinyl Butyral, Kaolin, Paperdust, acetone, amyl acetate, Xylene and Water. These areas were then coloured in using dry colour pigment and a solution 2% w/v B72. Paraloid in Xylene.

This method proved to be very successful on the Auckland dendroglyphs and it is proposed that those held in Dunedin's Otago Museum will be consolidated in the same way.

Conclusion

The treatment for the dendroglyphs held in the Museum collections will ensure that they will be preserved for future generations. However, the ones remaining in the bush are certainly in danger of disappearing unless the remaining groves are protected from farm activities such as clearing and cattle grazing and of course the fossicker with his chainsaw. The New Zealand Historic Places Trust and Government have a responsibility for our future generations to protect the dendroglyphs. A simple farm fence would seem to be all that is necessary.

It is worth mentioning one proposal put forward by a New Zealand ethnologist who suggested that the dendroglyphs be cut out of the trees, fibreglass casts made, which could then be placed back on the trees!

Suffice to say that this proposal did not find much favour with the rest of the Museum community in New Zealand, for one, I would not like to take a walk in a forest with fibreglass dendroglyphs staring one in the face.

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CLEANING OF EARLY FEATHER GARMENTS FROM SOUTH AMERICA AND HAWAII

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SUMMARY

Recently two different cleaning methods were applied on a large number of ethnographic feather garments. In order to understand the methods chosen, there follows a brief description of the structure of contour feathers and down feathers. Some experiments were carried out before the final cleaning methods - respectively dry-cleaning and washing in water were chosen.

At the Conservation Department of the National Museum ofDenmark, Brede, a large number of feather garments from the Department of Ethnography have recently been cleaned.

The Tupinamba feather garments
In 1979 some feather garments made by the Tupinamba Indians in Brazil were treated. The garments, 18 in all, were recorded in the 1690 inventory of the Royal Danish Kunstkammer. The feathers used on the garments are mainly of the bird Red Ibis. Furthermore parrot feathers of the Red Ara are used. Most of the larger pieces of clothing have a net-base made in the same way as fishing nets. The strings used for the net base and for tying on the feathers were spun with fibres from the pineapple species; others were of cotton.

Deterioration caused by moths, fading, wear of feather edges and dirt deposits was considerable on some garments, while others were quite well preserved.

The Hawaiian down feather cloak and helmet
A garment from Hawaii consisting of helmet and cloak with red and yellow down feathers was cleaned in 1981. It has been in the National Museum since the middle of the 19th century. The exact age is unknown. Down feathers are fastened in bundles of app. 20. On the cloak the bundles are tied to a very fine-meshed net and spun with a plant fibre from the pineapple family. The garment was well preserved except for the helmet, on wich the yellow band was worn and faded. On the helmet the down-bundles are tied to a woven bast shape.

It is obvious that the deterioration mechanisms work together so that the presence of dirt gives nourishment to moths and brings about fading and the further deterioration of the feathers. Therefore we decided to clean the garments in order not only to delay the deterioration process, but also to restore to these exhibits some of their former splendour.

The structure of the feathers
In order to explain why we chose to clean the contour and down feathers by dry-cleaning the former and washing the latter in water, the structure of feathers will be described briefly:

All parts of a feather consist, just like hair, wool and horn, of the protein keratin. While the feather grows, the protein-producing cells in the bottom of the calamus receive nourishment and pigments through the hole in the calamus. When the feather has reached its full size, the cells die and the keratin hardens. The protein forms a network of cell walls which form layers of varying density and contain thousands of small air pockets. This porous structure with the presence of pigments produces many reflecting and refracting surfaces in the keratin. This results in iridiscence, which is an important quality in the feather.

A feather consists of quill, barbs and barbules (fig. 1). Contour feathers have a stiff central quill and parallel barbs with interlocking hooklets or barbicels. Down feathers have a reduced quill and the barbules have no hooks, making the barbs fluffy without connection with one another.

One should be aware that feathers may have been dyed, and this together with the degree

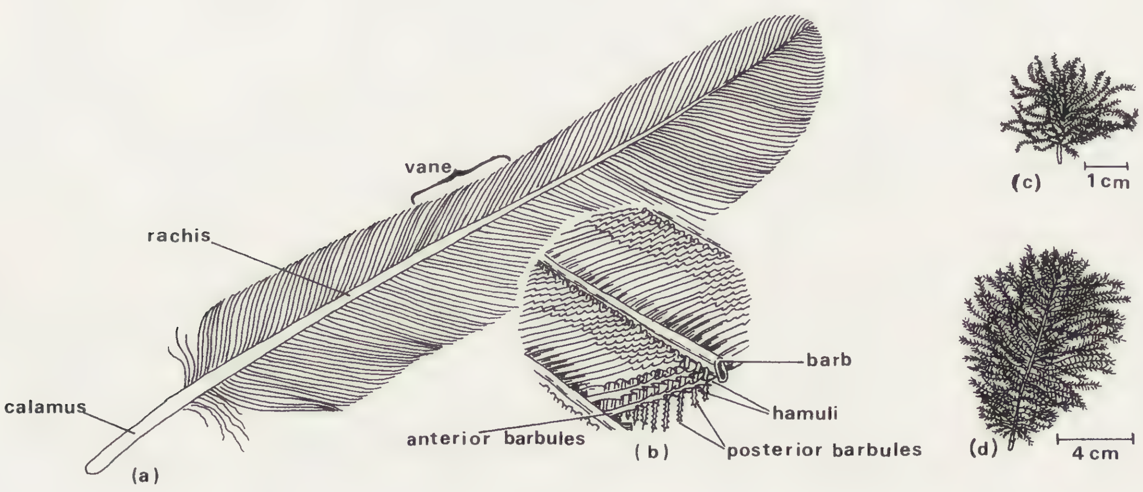

Fig.1. Typical fleight feather.(a)Full view.(b)Detail of vane.(After J.Van Tyne and A.J.Berger, Fundamentals of Ornithology,Wiley 1959)(c)Down.(d)Semiplume.(After J.C.Welty.The Life of Birds,Saunders,1962.

of deterioration is decisive in the choice of cleaning method. The mounting of feathers in connection with other materials makes the choice of cleaning method even more difficult.

Washing and dry-cleaning experiments

Before the cleaning of the Tupinamba feather garments, some tests were carried out, based on existing literature.

Cleaning by brushing and vacuum-cleaning alone was not sufficient. We avoided cleaning methods which we considered would put too much stress on the feathers, such as removal of dust by first brushing on potato flour (similar to corn starch) and then using compressed air or airbrasive.

First was tried a cleaning with foam of detergent whipped in water (2). The method was unsuitable, because it resulted in dirt blotches on the feathers, even when the brushed-on foam was quickly removed. When washing in water, with and without detergent, it was obvious that water made the worn feather edges entangle, and furthermore made the barbules stick together in bundles. This unfortunate property of water on contour feathers is also observed by S.Wolf (5).

Washing the feathers in water was abandoned, and the cleaning had to be done by dry-cleaning. We tried a 4% Vulpex B 30 (from Frank Joel), a potassium oleate soap dissolved in dichlorethylen (2) without any good result.

Asorpon BC (from Hoechst), a dry-cleaning detergent mixed with a small amount of water and dissolved in white spirit, is frequently used for cleaning textiles. This cleaning method was not very efficient either, even though the feathers were treated with ultrasound and brushed carefully.

Searching for a satisfactory cleaning method we tried a cleaning solution which is used in modern dry-cleaning machines. It consists of Frigen 11S, a trichlorfluormethan (from Hoechst), mixed with a dry-cleaning detergent Fluoro-mat (see technical data), with a small amount of water.

Frigen 11S reaches boiling point at 23,8°C and should only be used in closed systems. Some feathers treated in a dry-cleaning machine became very clean, but this mechanical treatment was not suitable for fragile museum objects. Dry-cleaning and dry-cleaning detergents are described by J.W.Rice (6).

Dry-cleaning the Tupinamba feather garments

We decided to continue our experiments with the dry-cleaning detergent Fluoro-mat now dissolved in white spirit. This made it possible to handle the feathers in open vessels. By using the following recipe the result of the experiments came out satisfactory: 5 ml Fluoro-mat, 2,5 ml distilled water, 1000 ml white spirit (Shellsol TD). The Fluoro-mat and distilled water are mixed and the Shellsol TD slowly added while stirring.

Before dry-cleaning, the garments were carefully brushed and vacuum-cleaned, loose feathers were sewn on and the net-base was mended.

When vacuum-cleaning one should be aware that considerable amounts of insecticides such as D.D.T., paradichlorbenzen and Lindane are very often present in old museum objects.

The garments were soaked for 1 hour in the cleaning solution preheated to 28°C. The feathers were then brushed with soft brushes and for a short period treated with ultrasound. The work was done in a porcelain sink, which gives a good resonance for the ultrasound. The treatment lasted for 1-3 hours, and during that time the objects were frequently sloshed gently.

Rinsing was carried out in 4 shifts of clean Shellsol TD. The rinsing baths were filtered and reused several times, but the last rinse was always freshly tapped.

Each feather was adjusted by hand while the garments were still wet. When one row of feathers was in order, it was blown dry with cool air.

The dry-cleaning method was not suitable for garments made of down feathers. The down barbules entangled after cleaning. Drying in an air stream and manual treatment helped very little in making the downs fluffy again.

When working with white wpirit this should be done in a well ventilated room and with the use of suitable gloves and gas masks. When using ultrasound and airblowers, hearing protectors should be worn.

Treatment of the Hawaiian garment

The unfortunate effect of the dry-cleaning solution on the down feathers was again observed when the Hawaiian garment was to be treated.

Therefore we tried washing in water with a nonionic detergent on som loose downs. Unlike contour feathers, down feathers are not damaged by water, for as mentioned earlier they differ in physical structure. - When the down feathers were examined under microscope after washing, it was obvious that they had regained their fluffy look.

We chose the detergent Tinovetin J.U. (see technical data), which is also used when washing old textiles, and tested the method on a corner of the cloak. When the dry-cleaned and the washed areas on the cloak were compared, the latter appeared much cleaner.

Measurements made before and after the washing of the cloak showed no shrinking of the net-base.

According to Wolf (5) and Rice (6), washing in water causes hydrolysis which is damaging to the protein of the feather. Water should be especially bad for already deteriorated feathers, but as mentioned the Hawaiian down feathers were in good condition.

We applied a washing treatment which is often used on old textiles.

The loose dust was removed by gentle brushing and vacuum-cleaning. The cloak was then placed on an aluminium frame covered with nylon net and soaked in a large plastic sink in distilled water with o,o5% Tinovetin J.U. at 32°C.

After 30 minutes the water level was raised to about 3 cm above the feathers. This made the ultrasound treatment easier. At the same time the concentration of the detergent was increased to 0,1%, and the temperature adjusted to 32°C. The brushing and the ultrasound treatment of the feather-side of the cloak lasted for an hour and a half. The lower edge being very dirty on the back, the edge was turned over and oblong balloons were placed in the fold, before treatment.

The cloak was rinsed in 4 shifts of distilled water. On the frame the cloak was gently sloshed in the water. While the sink was being drained and filled, the frame was lifted on a couple of cross girders (photo 1). In this position the cloak also dripped off overnight,

covered with a plastic sheet to avoid drying of the downs on the top.

The drying was done with an air blower with cool air mainly blown through the downs from the back. The cloak was placed over a plastic-coated pipe (photos 2, 3). When almost dry, the downs were adjusted with soft brushes. The cloak was left on the frame for three days to allow it to dry up completely.

On the helmet a small area was washed at the time with a 0,1% Tinovetin J.U. solution in distilled water. The solution was brushed on and sucked up with paper tissue. The rinsing was done in the same way. On the helmet the downs were dried from the front.

Conditions of storage and exhibition

Moth attack: Both when stored and exhibited, feathers should be placed in dustproof areas, as they are very vulnerable to the attack of moths.

We suggest the use of Vapona Pest Strips (from Shell) to avoid the invasion of moths and other insects.

Insecticides as Lindane should not be used as the crystals may cause damage to the fine struckture of the barbs.

Insecticides containing paradichlorobenzene should not be used as they are likely to accelerate the fading of colours in the presence of daylight.

The optimum climate for moths is a temperature around 25°C and a RH higher than 60%. If these conditions are present, four generations of moths may be hatched in one year.

Dust: As very few museum stores are free of dust it is necessary to wrap the feathers in acid-free tissue paper and pack them in acid-free cardboard boxes. The dust abrades the feather's fibres, and additionally dust contains sulphur dioxide from the air pollution, which may increase the fading of the colours.

Light: When exhibiting feathers the UV light should be eliminated, and the intensity of light should not exceed 90 Lux. Preferably feathers should be illuminated only when they are being looked at.

Temperature and RH: The temperature should be app. 15-18°C and RH 50-55%.

Technical Data

Fluoro-mat: A dry-cleaning detergent made by Simon u. Dürkheim, Dieselstrasse 4, 6052 Mühlheim/Main, West Germany.

The detergent consists of app. 50% anionic and non-ionic tensides, spindle oil, glycol, alcohol and water.

The manufacturer recommends the following recipe for dry-cleaning: 2 ml Fluoro-mat and 1 ml water mixed in 1 l of fluorcarbon for dry-cleaning.

It may be possible to reduce the concentration of the detergent in white spirit as well. If this is done it might also be possible to reduce the number of rinsing baths. The manufacturer states that the other components of the detergent are harmless to the objects, they will only cause them to become anti-static.

Shellsol TD: White spirit from Shell with a

Photo 1. Change of distilled water while rinsing the cloak.

very weak odour. Boiling point: 168-190°C. Flash point: 46°C. The relative evaporating rate is 0,14 (Ether = 1).

Tinovetin J.U.: Non-ionic detergent from Ciba-Geigy. It is an acryl-aryl-polyglycolether. As the washing effect seemed to be sufficient, it was not necessary to add any phosphates or carboxy methyl cellulose (CMC) to the washing water.

Vapona Pest Strips: Produced by Shell. Vapona Strips are hung in dustproof rooms or showcases. During 10-15 weeks they liberate a controlled release of the vapour phase insecticide dichlorvos. 1 strip should be used per 28 m^3.

Dichlorvos is a phosphor containing cholinesterase inhibitor which kills insects in concentrations down to 0,02 mg/l.

The TLV in Denmark is 1 p.p.m.

Shell states that if the strip is used according to the instructions, the maximum concentration will never exceed 0,05 p.p.m.

Ultrasound equipment: An equipment developed recently by Reson System Aps. It has an adjustable kHz regulation and a separate ultrasound sonde. The work was done at 23,0 kHz, equivalent to 200 dB.

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Photos: Niels Erik Jehrbo.

Photo 2. Drying the cloak with airblowers from the back.

Phot 3. While drying from the back the downs were arranged on the front.

Section 4

Documentation

Documentation

DOCUMENTATION

Coordinator : S. BERGEON (France)
J.-M. ARNOULT (France ; interim since oct. 1983)

Programme 1981-1984

I. Utilisation des symboles dans la documentation graphique.
"Elaboration d'un système descriptif des altération des tableaux" : M. BOGOVCIC (Yugoslavia).

II. Thesauri.
- Papier : Mme FLIEDER (France)
  M. COOK (Australia)
- Textiles : Mme HOFENK DE GRAAF (Netherlands)
  Dr LEENE (Netherlands)
  Mme BURNHAM (Canada)
- Pierre : M. STAMBOLOV (Netherlands)
- Matériaux siliceux : Mme SALDANA DE GOUST (Spain)

III. Bibliographie des divers groupes de travail
- Sculptures polychromes : M. Van ASPEREN DE BOER (Netherlands)
- Peinture murale : M. MORA (Italia)
- Papier : M. ARNOULT (France)
- Training in conservation and restoration : M. VON IMHOFF (Switz)

IV. - Documents descriptifs (fiches techniques, rapports de restauration, etc.)

- Rapports de restauration au Service de la restauration des peintures des Musées nationaux (Paris).

- Documents descriptifs : études et comparaisons dans divers centres européens (par un collaborateur du S.R.P.M.N., Paris).

V. Les expositions sur la restauration.

- Expositions de restauration par le Service de restauration des peintures des Musées nationaux (par un collaborateur du S.R.P.M.N., Paris).

POUR UN AVENIR DE LA DOCUMENTATION

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Paris
France

SUMMARY

L'organisation de la recherche documentaire est complexe et il semble que les spécialistes de la conservation et de la restauration sous-estiment son importance pour l'accomplissement de leurs travaux. L'analyse des difficultés propres aux techniques de mise en oeuvre de l'information conduit à proposer des solutions qui permettraient aux utilisateurs une meilleure exploitation des ressources documentaires, et justifieraient l'utilité du groupe de travail "Documentation" au sein du Comité de la conservation de l'ICOM.

En 1969, à Amsterdam, quelques personnes convaincues des vertus de la documentation, créaient un groupe de travail décidé à se charger de réfléchir à des propositions concernant les techniques documentaires dans le domaine de la conservation et de la restauration.

A la lecture des divers rapports publiés depuis lors, à l'occasion des assemblées triennales de l'ICOM, on s'aperçoit d'une certaine ambiguité quant à la conception de la documentation qui s'y exprime. S'agit-il de préliminaires à une élaboration d'un système international à l'aide de réflexions éparses mais liées par un désir commun d'aboutir ? S'agit-il de la juxtaposition d'expériences individuelles, ponctuelles, dont les points communs se discernent mal a priori ? Quels bénéfices en ont été tirés, tant par les promoteurs que par les observateurs ? Aucun bilan n'ayant été dressé, il est malaisé de répondre précisément à ces questions qui reflètent la difficulté à dominer le problème de la documentation dans le domaine de la conservation et de la restauration, et la difficulté des spécialistes à maîtriser la recherche des informations dont ils ont besoin pour leurs travaux. La conséquence tangible, avec d'autres raisons sans doute, est la perplexité qui frappe le groupe de travail "Documentation" et qu'il appartient à tous ceux qui se sentent directement concernés, et au Comité de la conservation de l'ICOM, de dissiper en proposant les solutions qu'il conviendrait d'adopter pour que ce groupe assure son avenir et confirme son utilité.

Il n'est pas nécessaire de vanter les mérites de la documentation pour l'exécution de travaux sérieux sur des objets qui ont une structure matérielle et intellectuelle que tout conservateur, restaurateur ou scientifique se doit de connaître. On sait que cette connaissance ne se limite pas à une attitude purement passive (histoire et examen de l'objet et de ses constituants, etc.) ; elle doit aussi être prolongée par une attitude active (détermination réfléchie des meilleures techniques à utiliser pour restaurer cet objet, par exemple ; ou exploitation des conclusions en guise d'enseignement ultérieur pour la connaissance de l'objet, etc.), qui nécessite une recherche documentaire plus complexe. En conclusion, les professionnels utilisent deux types d'informations : l'un tiré de l'objet lui-même lors de son analyse matérielle ; l'autre de la littérature existante. Ces deux attitudes complémentaires font appel à deux acceptions de la documentation : l'une fondée sur l'utilisation des techniques destinées à organiser rationnellement les informations recueillies ; l'autre sur la simple recherche bibliographique.

C'est le premier point qui a retenu l'attention des membres du groupe de travail depuis 1969, et leurs nombreuses contributions témoignent de leur activité louable pour répondre aux besoins qui existent dans ce domaine. Ces besoins correspondent d'ailleurs à une réalité précise qui est le fait d'un souci d'organisation et de gestion des informations dans des services trop souvent habitués à travailler de manière isolée. Les politiques patrimoniales qui se développent actuellement dans beaucoup de pays, la prise de conscience des problèmes de conservation et de restauration, amènent les spécialistes à rechercher l'efficacité et la rationalisation du traitement de l'information : thesauri, questionnaires de restauration, introduction progressive de l'usage de l'ordinateur dans le traitement des renseignements relatifs aux objets, etc. De multiples efforts ont été consentis, mais on ignore malheureusement les suites qui leur ont été données, et le profit qui en a été tiré. L'évaluation est certes difficile et délicate ; ces interrogations entraînent néanmoins d'autres questions qu'on est en droit de poser : cette acception de la documentation est-elle dans une impasse ? Est-elle orientée vers les besoins des professionnels de la conservation ? Doit-elle être poursuivie ? Qu'attendent de la recherche documentaire les spécialistes ? La seconde acception qui a été - sans doute volontairement - délaissée, ne devrait-elle pas devenir une préoccupation du groupe de travail ? A cette dernière question, on peut répondre que les répertoires bibliographiques ne manquent pas.

On connaît l'*Art and Archaeology Technical Abstracts* qui dispense deux fois par an les références envoyées par ses correspondants dispersés dans le monde entier. Cette bibliographie courante, contribution de l'International Institute for the conservation of historic and artistic works, loin d'être exhaustive, est cependant la seule à être diffusée régulièrement ; mais il n'est pas certain qu'elle soit acquise par tous les ateliers ou laboratoires, ni quelle soit consultée comme on le supposerait.

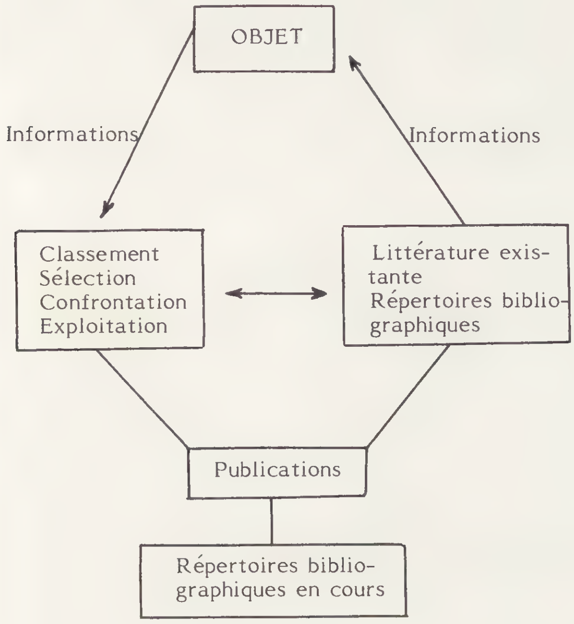
On connaît aussi les catalogues de la bibliothèque de l'ICCROM à son siège de Rome. Instruments de travail remarquables, ils couvrent un champ considérable et concernent tous les domaines de la conservation et de la restauration. Mais, ce ne sont que des catalogues dont la remise à jour est irrégulière et la diffusion restreinte.

A ces deux publications, on ajoutera les bibliographies signalétiques ou analytiques qui paraissent dans les revues techniques et professionnelles, ou dans les publications propres à certains établissements (musées, bibliothèques, centres de recherche). A dire vrai, cette masse bibliographique est énorme, désordonnée, parfois redondante, souvent incomplète, difficilement contrôlable par les spécialistes isolés ; mais son existence prouve, tout à la fois, la vitalité et l'anarchie de la documentation. Toutefois, seuls les centres bien équipés ont la possibilité de traiter ou de sélectionner ces références.

Mais, en définitive, le problème ne réside pas uniquement dans la recherche des références bibliographiques sur un sujet ou sur un objet. La difficulté à laquelle se heurtent les chercheurs est l'acquisition de la littérature dont ils ont besoin. Si les échanges internationaux ont progressé avec rapidité au cours des dernières décennies, on ne peut guère affirmer qu'ils ont profité aux institutions muséographiques ou scientifiques, encore moins aux spécialistes. Hormis par des relations personnelles établies lors de visites, de congrès, relations souvent amicales, il leur est difficile d'acquérir ou de consulter certaines publications dont la diffusion est limitée à des cercles restreints, professionnels ou géographiques. Doit-on conclure que ce type de relations est l'aboutissement logique d'une politique documentaire à l'échelon d'un pays ou au niveau international, et qu'il convient de l'officialiser ?

Tels sont, rapidement esquissés, les deux aspects des préoccupations documentaires qui animent les membres du groupe de travail. Sans vouloir évoquer dès l'abord des solutions, il est intéressant cependant d'analyser ici ce qui nous semble être la conception actuelle de la recherche documentaire, et de cerner les problèmes rencontrés. La documentation étant prise dans son sens général - incluant les deux acceptions signalées plus

haut -, nous attacherons notre réflexion plus précisément aux utilisateurs et aux informations car il nous apparaît, en effet, que les difficultés sont d'abord liées à des imprécisions au niveau du concept de documentation.



La première difficulté réside dans la dispersion et la diversité de l'information, qu'elle soit recueillie à la source (objet) ou supposée latente dans la littérature existante (sciences, techniques, histoire, ethnographie, etc.). Les ateliers ayant à leur disposition des centres d'information structurés, capables de regrouper ou de détecter et d'organiser rapidement des informations de toutes provenances, ne sont malheureusement pas très nombreux. Beaucoup d'ateliers, ou de laboratoires, travaillent avec des moyens faibles, voire désuets, considérant encore que la documentation n'est qu'une auxiliaire non spécifique de la conservation et de la restauration ; ils se contentent de rassembler des informations de manière pragmatique, sans souci d'utilisation future, et de collecter des références bibliographiques glânées au hasard de lecture de revues, incapables d'amener cette documentation primaire jusqu'aux utilisateurs. Et si le rôle des revues est important, encore faut-il y être abonné. Ces évidences surprendront peut-être ; elles reflètent cependant une réalité fréquente. La dispersion des sources documentaires n'en est que plus tragique pour ces ateliers qui sont contraints de rêver devant des références bibliographiques inaccessibles ou des informations inexploitables. Nous ne signalerons que pour mémoire - car tous les spécialistes en sont conscients - que cette situation est préjudiciable aux objets, bien entendu.

La seconde difficulté réside dans l'impréparation des utilisateurs aux techniques documentaires. Cette impréparation est-elle dommageable ? Certes pas, car l'utilisateur n'est pas censé être aussi un documentaliste ; qu'il connaisse les ressources de la documentation et la nécessité d'y recourir est déjà important. Mais, est-ce suffisant ? Comment peut-il exploiter correctement des informations s'il connaît mal les méthodes propres à cette technique particulière ? On regrettera que la formation des spécialistes (scientifiques, conservateurs, restaurateurs) dédaigne trop souvent l'initiation à la recherche bibliographique et à l'organisation de l'information.

Ces difficultés ne sont pas exhaustives ; elles prouvent cependant qu'il est malaisé, pour un groupe de travail "Documentation", de proposer son aide et de déterminer un programme de recherche cohérent et utile.

Il semble bien, en conclusion, qu'une véritable politique documentaire repose sur un certain nombre de principes qu'il est indispensable de formuler. Faute de les mettre en oeuvre, on se limitera longtemps encore à des balbutiements. Ces principes peuvent s'exprimer en trois propositions : connaissance de la réalité documentaire, collaboration, adaptation à des techniques nouvelles.

La première proposition n'est pas la moins importante. En effet, comment susciter une politique de la documentation sans avoir une notion précise des besoins ? Il revient aux professionnels de dégager les grandes lignes de leur attitude en face de la recherche documentaire qui leur est nécessaire. S'il est utile de savoir qu'un scientifique a besoin de publications scientifiques, un restaurateur d'études techniques sur des objets ou des matériaux, il paraît plus utile en revanche de savoir comment ces spécialistes conçoivent le rôle de la documentation, que ce soit au niveau de la recherche bibliographique ou de l'organisation de l'information. Enfin, il conviendrait de savoir ce qu'ils attendent de la documentation. L'analyse des besoins n'est pas simple, mais elle conditionne la mise en place de solutions efficaces.

Le second point est, lui aussi, important. Aucune politique documentaire n'est possible sans une collaboration étroite de tous à différents niveaux. Dans l'hypothèse souhaitable de l'instauration d'un système de coordination, celui-ci aurait pour tâche de coordonner ce qu'on voudra bien lui apporter, selon la vérité que les petits ruisseaux font les grandes rivières. Au désir de codifier une telle politique, il faut bien opposer l'inertie inhérente à toutes les institutions ; mais la volonté de réaliser une oeuvre commune utile à tous est en mesure de vaincre ces obstacles. Une collaboration entre les producteurs de l'information, ceux qui la reçoivent, ceux qui la gèrent, et ceux qui l'utilisent, entre les ateliers, les laboratoires, les musées, les centres de recherche, et les bibliothèques, constituerait une chaîne dont la réalité dépend d'une organisation précise et d'efforts volontairement consentis par tous les participants.

Enfin, ces solutions ne sauraient dépendre de la seule bonne volonté ; elles sont tributaires de moyens à mettre en oeuvre pour aboutir à un résultat tangible ; elles relèvent également d'un souci d'utiliser judicieusement des techniques contemporaines. L'informatique est certainement la ressource technique la mieux adaptée aux problèmes de la restauration. Faut-il considérer comme utopique une base de données internationale ? Faut-il rêver, ou faut-il agir sans attendre ? Des décisions importantes doivent être prises rapidement pour permettre aux professionnels de maîtriser la documentation, puis de préparer la création de banques de données pour les prochaines décennies. L'ambition d'un tel projet n'échappera à personne, pas même aux plus crédules. Quant aux incrédules, peut-être trouveront-ils, dans leur expérience, la sagesse de croire en l'avenir ?

Quel rôle pourrait jouer le groupe de travail "Documentation" du Comité de la conservation de l'ICOM ? Il ne nous appartient pas particulièrement de le définir ; il appartient à tous ceux que le problème préoccupe de prouver que la documentation n'est pas une simple auxiliaire, jamais parfaite, toujours incomplète. Si la réflexion sur les problèmes documentaires est indispensable, c'est qu'elle est à la base même des solutions futures (élaboration de thesauri, étude des problèmes propres à certains domaines, etc.).

Mais à ce rôle de réflexion qui lui revient, le groupe de travail devrait joindre la préparation des études nécessaires, dans un premier temps, à assurer la coordination d'une base bibliographique née de la collaboration la plus large possible. A l'issue de cette étape, l'analyse des résultats permettrait de déterminer l'évolution des travaux qu'il serait souhaitable de proposer.

Ce programme n'est qu'une esquisse sommaire soumise à l'attention des spécialistes ; il est aussi une mise en garde contre l'autarcie documentaire, héritage ancien mais toujours vivace, qui va à l'encontre des impératifs contemporains de conservation des patrimoines.

DOCUMENTING TWENTIETH CENTURY AMERICAN ART UNDER THE JURISDICTION OF THE GENERAL SERVICES ADMINISTRATION

Arlene Quint Platt
Fine Arts Management Specialist
General Services Administration
18th and F Streets, N.W.
Washington, D.C. 20405
USA

SUMMARY

The U.S. General Services Administration (GSA) is entrusted with the care and preservation of about 101,000 Federal artworks dispersed nationwide. GSA's comprehensive approach to documenting twentieth century American art for conservation purposes includes the maintenance of standardized conservation contracts, examination reports, treatment records, and proper photographic documentation. This paper discusses GSA's unique documentation tools: its questionnaires pertaining to artists' materials and their recommendations for future care, maintenance, and treatment and a computerized information management system that addresses conservation documentation needs.

The U.S. General Services Administration, through its Public Buildings Service, is responsible for the care and preservation of about 101,000 works of Federal art. To satisfy agency needs as well as demands from curators, conservators, scientists, and other museum and conservation professionals for quick access to conservation documentation for individual works of art, GSA maintains comprehensive conservation documentation.

Permanent files are maintained in GSA's Central Office located in Washington, D.C. In addition, copies of conservation documentation for artworks commissioned by GSA's Art-in-Architecture Program are kept in GSA's regional and local offices.

Federal art under GSA's jurisdiction consists of approximately 100,000 objects produced during the New Deal programs of the Franklin Delano Roosevelt era from 1933-1943; over 200 American works of art commissioned by GSA's Art-in-Architecture Program from 1962 to the present; and artworks associated with historic Federal structures, such as Daniel Chester French's sculptures for the New York Custom House. These Federal artworks are dispersed nationwide in public buildings, museums, schools, colleges, libraries, hospitals, and prisons.

New Deal Documentation

For federally supported New Deal artwork from 1933-1943, GSA maintains conservation documentation filed by artist and building. GSA's original mandate for documenting and preserving the surviving works of art of this period came directly from the Federal Property and Administration Services Act of 1949 which established GSA and, in the process, transferred to the Agency "all records, property, personnel obligations, and commitments of the Federal Works Agency (FWA)." Those agencies of the former Federal Works Agency included the Section of Fine Arts, the Public Works of Art Project, the Treasury Relief Art Project, the Federal Art Project of the Works Progress Administration, and the Art program of the Works Projects Administration.

Original conservation documentation includes the Treasury Department's Technical Bulletins which contain technical advice to artists especially on painting materials and processes. Artists' questionnaires of the era are also preserved. The files have been invaluable in GSA's continuing efforts to examine, restore, and preserve the surviving works of art of this period. They have also been used by researchers from the National Museum of American Art, Smithsonian Institution, Washington, D.C., which is the official depository of New Deal art retrieved by GSA, and from other museums and institutions where artworks produced by the programs are displayed or on loan.

Art-in-Architecture Questionnaire

Each artist commissioned by GSA's Art-in-Architecture Program has been requested to complete a standardized artist's questionnaire after the artwork is installed. The new form, designed in 1980, requests information about artist's materials and recommendations for future care, maintenance, and treatment. The same questionnaire is used for paintings, sculpture, photographs, tapestries, craftworks, and stained glass. The complete questionnaire aids in determining the original physical nature of the artwork and--by comparison--its present state, its deterioration, and its need for conservation treatment or maintenance. In addition, during contract negotiations, a copy of the completed questionnaire is provided for information only to conservator-bidders along with GSA's standardized conservation contract. After a conservation contract has been awarded, GSA encourages continuous dialogue, whenever possible, between the artist and conservator.

The completed questionnaire, however, is not always "the last word" in choosing a conservation treatment. For instance, the treatment and maintenance suggested by the artist are not always satisfactory because the artist may be unfamiliar with conservation principles and practices. Also, the questionnaire does not address environmental conditions or safeguards in public spaces. GSA is aware that art in public places--as opposed to that in museum environments--are not well protected from such environmental factors as air pollution, light, humidity, and temperature variations. In addition, circulation of the public around the artwork sometimes leads to physical contact with the artwork, such as touching and, in extreme cases, vandalism. Therefore, GSA does ask the artist about the stability of his or her materials and their future behavior in a public location and requests recommendations for environmental safeguards and security measures. GSA introduces the topics when the artist submits a concept for review and approval by the Design Review Panel, before proceeding with the final work; and, again, during the execution and installation of it.

During the talk, examples of artists' questionnaires completed by Al Held, George Sugarman, Isaac Witkin, Richard Serra, Dan Flavin, Steven Antonakos, William Christenberry, Yvonne Jacquette and other contemporary artists as well as those completed by such New Deal artists as William Gropper, George Harding, Alfred Crimi, and Ben Shahn will be presented. Comparisons will be made between individual artist's recommendations for future care, maintenance, and

Section of Painting & Sculpture   Dept. Justice Bldg., Wash., D.C.

STRUCTURAL

1. What is the surface material of the wall at the present time?

Plaster

2. State whether the walls have been painted and the kind of paint used.

yes, and it appears to be a flat oil paint -

3. What preparation of the wall, if any, is necessary before installation of the work?

none that I know of.

4. What treatment does the artist propose to use for protection against possible dampness from the wall?

The canvas will be mounted with white lead and varnish or casein glue and both are fairly waterproof -

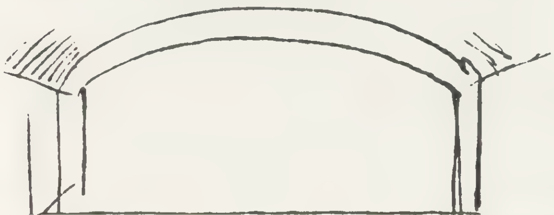
LIGHTING

1. Do any lighting fixtures obstruct the view of the murals?

no -

2. Could the lighting fixtures be raised?

3. What suggestions does the artist offer to correct the lighting?



The front member of the moulding should be treated to harmonize with painting and should be done when painting is being mounted -

Name of manufacturer of the paints to be used for the work.

Bocour artist Colors - Fezandie & Sperrle imported colors -

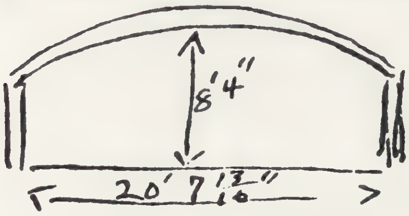
. A sample of the canvas or ply board to be used must be submitted.

Sample of canvas prepared myself Scotch linen -

3. What method does the artist propose to use in securing the murals to the wall?

Canvas will be pasted to wall surface with casein or lead and glue -

4. Final dimensions of the murals?



John Steuart Curry
(Name)
AAC

Oct. 6th-36-
(Date)

Fig. 1 GSA New Deal Art Artist's Questionnaire for John Steuart Curry's Land Rush in Oklahoma

GSA ART-IN-ARCHITECTURE ARTIST'S QUESTIONNAIRE

Artist: Claes Oldenburg

Title of work: 100' Bat Column

Completion date: April 12, 1977

Location: S. S. Bldg. Great Lakes Program Center, Chicago, Illinois

Dimensions: height x width x depth in feet and inches 100' 8" x 9'9"(top diam.) x 54" (bottom diam.)

Weight: 40,000 lbs.

Construction, composition of the work (for the following, please use dates, methods, and products used):

1. Materials (kind, variety, quality; preparatory work, joining of blocks, hollowing out, etc.).

   Execution - Materials consist of cor-ten steel and aluminum assembled as a welded construction in one piece.

2. Medium or construction (Description of assemblages, materials, and methods).

   Materials - primarily 5/8" x 3" cor-ten bar, 2" square cor-ten tubing and cast aluminum segments for the knob. Exterior surface is made up of 24 vertical bars. Innerstructure consists of 2" sq. cor-ten steel tubing. Knob at base consists of 24 cast aluminum sections welded together.

   Support:

   Foundation provided by others.

   Medium:

   Ground (preparation of surface before painting etc; adhesion, cohesion)

   Entire sculpture was sandblasted, primed and painted, using a urethane paint system.

   Paint Layer:

   The sculpture has three coats of paint. The paint used was specially mixed by Sherwin-Williams, using the following formula:

   SPECIAL FORMULA POLANE GRAY

7 1/2 parts of #F63A13 7B	Polane Gray
3 parts of #F63B13	Polane Static Black
2 parts of #F63T1	Polane Flatting Base
16 oz. of #F63RB8	Polane Red

3. General recommendations for care and maintenance.

   The "BATCOLUMN" should be painted on a 3 to 6 year basis. A judgment must be made as to when the general condition and appearance of the surface dictates repainting. The frequency of complete painting can be extended by touch-up maintenance on a 3 to 4 month schedule.

Fig. 2 GSA Art-in-Architecture Artist's Questionnaire for Claes Oldenburg's 100' Bat Column

conservation treatment and the actual preliminary and final conservation treatment reports.

GSA's comprehensive approach to conservation documentation also includes the maintenance of copies of GSA's standardized conservation contract incorporating the American Institute for Conservation of Historic and Artistic Work's Code of Ethics and Standards of Practice, examination reports, treatment records, and photographic documentation. Archivally sound, 8 by 10 inches, both black-and white and color photographs are required before, during, and after conservation treatment.

FEDART

Recently, GSA has developed the requirements for a computerized information system ahout artworks, artists, and loans of the artwork. The system, called FEDART, contains conservation information that can be queried by condition code, last conservation treatment date, conservation treatment descriptions, last conservation inspection date, and next scheduled conservation inspection. The condition code details whether or not an artwork is in urgent need of conservation services.

Along with such data as accession number, title, artist, fabricator, printer, Federal Art Program, signature(s), signature date, dimensions, weight, and description of the artwork, data can be queried by object class and physical index terms. The object class groups Federal artworks with similar characteristics. For instance, the object classes are painting, sculpture, drawing, print, photomechanical, textile, construction, and minor arts. The object class "painting" is subdivided into mural, easel, miniature, etc.; "minor arts" can be glass, ceramic, skin, fur, and leather.

Physical index terms detail the artist's materials and techniques used. The artist's materials are divided into the categories of support, ground, size, paint layers, and surface coating. Queries can be further refined by using a thesaurus of artists' materials. Artist's techniques are processes and manufacturing methods which can be further subdivided by using another thesaurus.

Future additional capacities will include the ability to provide the user not only with data about the artwork but also with a pictorial representation of it. Whether such pictorial images are stored and displayed on a conventional laser video disk or on a optical digital data disk cannot be determined until the technology evolves further.

Comprehensive Conservation Documentation

By combining responses to artists' questionnaires, standardized conservation contracts, photographic documentation, conservation examination reports and treatment records, GSA has been able to develop a system for care and preservation of the twentieth century art entrusted to the agency. By automating the system, GSA hopes to make its art conservation program even more responsive.

A DATA FILE ON ARTISTS' TECHNIQUES COGENT TO CONSERVATORS

Joyce Hill Stoner
303 Old College
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Newark, Delaware 19716

SUMMARY

A data file on artists' techniques useful for paintings conservators has been established at the Ralph Mayer Center for Artists' Techniques under the Winterthur Art Conservation Program at the University of Delaware. The format for collection and retrieval is discussed. The file will be on Syntrex/Aquarius word processing equipment using List Processing/Sort Software. Additional contributions are encouraged.

BACKGROUND AND PURPOSES OF THE PROJECT

In 1976, a conference was held at the Brookhaven National Laboratory in Upton, Long Island, New York, on the use of computers in conservation. Rustin Levenson, then with the paintings conservation department at the Metropolitan Museum of Art, mentioned her card file of "little known facts" about artists' techniques--use of water soluble media and coatings by Miro, a recommendation by J. Nagel to mix varnish with vermilion, etc.--which she updates regularly. Perhaps entering this data onto a computerized network would facilitate both collection and retrieval by practicing conservators.

In July, 1980, an international symposium was held at the National Gallery of Canada on The Conservation of Contemporary Art. Several conservators gave papers reporting their cooperation with contemporary artists during the conservation treatment of particular pieces. Significant comments had been received directly from each artist regarding reactions to the use of varnish or attempts to retard deterioration. A number of papers addressed the necessity for documenting artists' materials and techniques through questionnaires, interviews, research, and careful technical records.

In December of 1980, Betty Fiske and Rita Albertson of the Winterthur Art Conservation Program interviewed artist Robert Motherwell. During the interview he noted that he abhors varnish on his paintings and has even gone to great lengths to buy back one of his paintings that he felt had been destroyed by varnishing. Where could information of this type be carefully stored for ready retrieval?

A survey was carried out by the author and Karen Weiss to gather a source list of technical information on contemporary art. Results from this survey were presented at the ICOM Committee for Conservation meeting in Ottawa, 1981. Thirty-three institutions or individuals who are compiling technical data on artists' material were identified in the Appendix of the ICOM preprint 81/6/1. Logistics and a lack of funds have restricted the development of a viable resource for ready information retrieval.

Using the volunteer network of Art and Archaeology Technical Abstracts as a model, a "seed" listing was sent to a number of interested paintings conservators immediately following the ICOM meeting of 1981. Contributions were received and entered into an Apple II plus computer using DB Master software to test that system for sorting and update flexibility. Thirty-three "files" on artists' techniques were then printed out and sent to thirty-six participating conservators, artists, and art historians in the fall of 1983. The number of file entries was doubled in the next several months, with a number of suggested avenues for collection and improved accuracy. However, the project was still without an umbrella for fundraising or staff time.

On December 29, 1983, Mrs. Bena Mayer, the widow of Ralph Mayer, noted author, art technologist and painter, signed an agreement with the University of Delaware, establishing the Ralph Mayer Center for Artists' Techniques, under the Winterthur Art Conservation Program sponsored jointly by the University of Delaware and the Winterthur Museum. The Center will be devoted to education, serve as an information resource center, and continue research into the durability of artists' materials. The Artists' Techniques Data File now has a home and a new Syntrex word processing system.

GUIDELINES FOR PLANNED CONTENT

Problems abound in collecting and verifying unpublished material in the field of conservation. Some references may be based on conservation "lore" or "legend" which has been passed through master/apprentice and supervisor/intern discussions with the sources long forgotten. At the Ottawa Contemporary Art symposium, one conservator announced that Sam Francis was "categorically opposed to varnish" on his works. Another conservator quickly reported that Sam Francis had just visited his studio to ask him to varnish one of the artist's paintings. It quickly becomes clear that there is no one answer to approaching the work of any artist, but no one argues the need for ready access to existing data.

Gay Myers, Conservator at the Lyman Allyn Museum, has made some important suggestions to steer the project away from becoming a "means to perpetuate doubtful myths."

Listings will be limited to three types:

1) Personal communication with artists--with information as to whom to contact for a transcript or details.

2) Written sources such as artists' treatises, descriptions of the artist at work, diaries or sitting book notations (with bibliographic references). Gwen Tauber, Winterthur intern now at the Los Angeles County Museum of Art has prepared a listing of 241 artists with one or more references to sources on their methods and materials. These sources will be researched and added to the file.

3) Findings of conservators from technical investigation or treatment--either published (with bibliographic source) or in a conservation file (with information on location of file.)

The intent is to collect facts which are potentially useful during the course of a conservation treatment. Facts such as pigments used or stretchers preferred will not be solicited unless that information would be cogent to a treatment choice. Data which might influence maintaining the artist's intent are particularly sought, e.g. a desire to avoid glossy varnishes or the use of readily soluble or heat-reactive materials.

As in Art and Archaeology Technical Abstracts, contributors and addresses for sources will be abbreviated and listed in an index to save space in the actual entries.

A contributors' form has been designed to facilitate accurate and complete future entries. A draft is reproduced:

UNIVERSITY OF DELAWARE
NEWARK, DELAWARE
19711

ART CONSERVATION PROGRAM
303 OLD COLLEGE
PHONE: 302-738-2479

THE RALPH MAYER CENTER FOR ARTISTS' TECHNIQUES

THE ARTISTS' TECHNIQUES DATA FILE
(Cogent to Conservators)

Name of artist: ______________________________

Born: ____________ Died: ____________ Nationality: ____________

Notes concerning the artist's materials and techniques: ______________________________

(Please continue on the reverse of the form if necessary.)

Source of information:

1. ☐ Personal communication with the artist. date: ____________
   Existence of further notes or transcript? ☐ yes ☐ no
   Location: ____________

2. ☐ Written source. bibliographic notation: ____________
   publisher, date, pg. no., etc.
   library or location of publication used: ____________

3. ☐ Technical investigation or treatment.
   conservator(s): ____________
   treatment(s) carried out: ____________
   (date, location)
   work(s) treated: ____________
   owner or location of work(s): ____________
   Known existence of further documentation of treatment? ☐ yes ☐ no
   Location: ____________
   Was this reported in a conference paper or other publication? ☐ yes ☐ no
   Reference: ____________

NOTE: If some information is confidential and cannot be released, please note that in lieu of the requested data.

Name and address of contributor: ______________________________

Date: ______________________________

Figure 1

SPONSORED BY THE HENRY FRANCIS DU PONT WINTERTHUR MUSEUM AND THE UNIVERSITY OF DELAWARE

"HARD" AND "SOFT" DECISIONS

As computer systems have invaded homes and museums internationally, conservators are becoming more aware of potentials and problems with "software," "data base management" and "word processing." Which system to use, when to buy and how much to invest are ever-updatable discussion topics.

This project began on Apple II plus hardware with 64K, and DB Master software, Version Three. Sample entries follow:

```
ARTIST: - PISSARRO, CAMILLE
BORN: - 1831
DIED: - 1903
NATIONALITY: - FRENCH
FACTS -        "PAYSAGE A CHAPONVAL"
RE. -           AT THE JEU DE PALME
TECHNIQUES -    IN PARIS HAS THE
1. -            INSCRIPTION ON THE
2. - BACK "VEUILLEZ NE PAS VERNIR
3. - CE TABLEAU. C. PISSARRO."
4. - DATE OF PTG IS 1881-82.  THE
5. - PTG HAS BEEN LINED SO THE
6. - INSCRIPTION IS NO LONGER VISI-
7. - BLE, BUT HAS BEEN RECORDED
8. - PHOTOGRAPHICALLY.  REF: MME.
9. - ANNE DISTEL, CURATOR, MUSEE
10. - D'ORSAY. LETTER TO JHS 4/24/
11. - 81.
```

```
ARTIST: - RUSCHA, ED
BORN: - 1937
DIED: - ____
NATIONALITY: - AMERICAN/CALIFORNIA
FACTS -        IN THE MID-70S, HE
RE. -          WORKED IN BLUEBERRY
TECHNIQUES - EXTRACT, EGG, BLOOD OR
1. - RHUBARB ON SATIN.  THE FADING
2. - OF THE NATURAL DYES IS CONSI-
3. - DERED BY THE ARTIST TO BE AN
4. - INTRINSIC AND IRREVERSIBLE
5. - CONDITION.  ANOTHER PAINTING.
6. - "WAR SURPLUS" WAS ROLLED UP &
7. - SHOWED CLEAVAGE AND LOSS UPON
8. - UNROLLING.  ARTIST APPROVES OF
9. - THIS CONDITION AND WISHES
10. - STABILIZATION BUT NO RETOUCH.
11. - REF: DENISE DOMERGUE, PRIVATE
12. - CONSERVATOR, LOS ANGELES,
13. - FROM CONVERSATIONS WITH THE
14. - ARTIST, ALSO CCA, 1980, CAN.
```

The forced limitations of file size, the number of characters per line (30), and lines per file (21), discourage explanations or comprehensive notations. Advantages are that the system will alphabetize, retrieve and print entries in a number of ways (by artist, date, nationality, etc.) and can readily be updated or edited.

The file will now be moved to a Syntrex/Aquarius with Listing Processing/Sort Software. Two sample entries follow:

SAMPLES

ARTIST: BEECHEY, SIR WILLIAM
BORN: 1753 DIED: 1839
NATIONALITY: British
Retouching over varnish

Beechey "has a custom of tempering his colors with a mixture of Jappanner's gold-size and turpentine....When finishing a picture, no matter how large it might be, he brushed it over with a mixture of spirits of turpentine and drying-oil, adding upon this the gold-size and turpentine, upon which, while they were still moist, he retouched the work. The process served as a varnish." From T. Sully, p. 36.

Ref. Hints to Young Painters by Thomas Sully, Reinhold Publ. Corp., N.Y. 1965, p. 36.
Source: Gay Myers, Conservator, Lyman Allyn Museum, New London, CT., USA.

ARTIST: KIRCHNER, ERNST
BORN: 1880 DIED: 1938
NATIONALITY: German
Use of a wax-oil medium

Kirchner commonly painted in a wax-oil mixture (a small handful of beeswax dissolved in one litre of benzine, used to dilute commercial oil colors).

These paintings were not meant to be varnished.
The artist particularly liked the matte fresh quality.

Ref: Chris Laely, student of Kirchner, MoMA files
Source: Kristin Hoermann, paintings conservation, MoMA, NYC, USA

This is an office word processing system rather than a personal computer, and the List Processing format has the same advantages as DB Master regarding sort, retrieval and update capabilities but none of the restrictive limitations on the size of each entry.

FUTURE PLANS

As with AATA, the value and variety of the information collected is dependent on the energy and participation of the contributors. And, as R. John Gettens noted about the contributors to the abstracts, they can be repaid by "their satisfaction in sharing in a worthy joint effort and in the appreciation that will be accorded them by scholars in art and archaeology in the years to come."[1] There is also the satisfaction of assisting with intra-conservation communication which may aid the preservation and maintenance of artists' intentions. Contributors will receive updated printouts, and investigation for means of wider distribution will continue. Xeroxes of the current file will be available upon inquiry as a service of the Ralph Mayer Center for Artists' Techniques.

I would like to relay special thanks to Gay Myers, Gwen Tauber, Rustin Levenson, Betty Fiske, Denise Domergue, Victoria Blythe-Hill, and Michael Heslip for their particular advices regarding directions and design for the project.

I am grateful to the seven conservators mentioned above also for their contributions to the file and to: Rita Albertson, Barbara Appelbaum, Marion Barclay, Hilton Brown, Carol Christiansen, Christine Daulton, Kristin Hoermann, Laura Juszczak, Robert Lodge, Mervin Richard and Charles Rhyne who have contributed important material.

To contribute or request information, please write: Artists' Techniques Data File, The Ralph Mayer Center for Artists' Techniques, c/o Winterthur Art Conservation Program, 303 Old College, University of Delaware, Newark, Delaware 19716, U.S.A.

Footnote:

1. IIC Abstracts, Vol. 2, No. 1, Spring, 1958, Foreward.

Section 5

Polychromed Sculpture

Sculpture polychrome

THE POLYCHROMY OF THE PORTALS OF THE GOTHIC CATHEDRAL OF BOURGES

Raffaella Rossi-Manaresi, Antonella Tucci

Centro "Cesare Gnudi", Via Pignattari 1, Bologna, Italy

SUMMARY

The polychromy of the monumental portals of the Gothic Cathedral of Bourges was studied. Examination of sample cross-sections, microchemical analyses and staining tests were carried out, supplemented by TLC and X-ray fluorescence analysis. The polychromy of the south lateral portal, first painted in 1225 and repainted after about 30 years (as emerged from the analytical results and historical information) shows some differences with respect to the polychromy of all the other portals (five in the west façade, one lateral facing north). Differences in the range of pigments and the medium used (oil in the south portal, casein in the others) as well as other variations in the technique were observed.

The polychromy of Gothic stone sculptures is discussed with regard to the painting technique on the basis of the present results,compared with those which have emerged from the examination of other sculptural monuments.

INTRODUCTION

The Gothic Cathedral of Bourges has five monumental portals in the west frontispiece and two lateral portals adorned with splendid stone sculptures which were originally polychromed.

The building of the west façade started in 1228-30; by 1255 the huge construction was finished and the five portals completed.

The sculptures of the lateral portals were carved in 1170-1175, when the decoration of the west façade of the old Romanesque cathedral with three monumental portals was projected. These sculptures were never set in the Romanesque façade, but were later reused in the south and north lateral portals of the new Gothic cathedral.

The south portal was built first, in c. 1225, and was used as the main entrance during the construction of the Gothic façade. The north portal was built later, maybe by 1232; it was certainly finished not later than 1255 (1).

The same stone, a limestone consisting mainly of mollusc shells (2), was used both for the sculptures carved in the 12th century (lateral portals) and in those of the 13th century (west façade portals).

The present note reports the results of the analytical study of the polychromy of these portals, aiming to investigate the original painting technique and identify overpaints and later treatments.

EXPERIMENTAL METHODS

A number of paint samples were studied: about 30 from the south portal, 25 from the north portal and 25 from the west façade portals (mainly the central one).

Sample cross-sections were prepared for observation under the microscope. Pigments and media were identified by microchemical analyses and staining tests, supplemented by X-ray fluorescence analysis carried out with the energy dispersive analytical system EDAX PV 9100 connected to a scanning electron microscope (SEM) Philips mod. 505.

Examination of some samples was also carried out by thin-layer chromatography (TLC). The chloroform extracts of the samples examined for the presence of oil and wax were chromatographed on silica gel using a stepwise development system (3).

All samples examined by TLC showed the presence of oil (absence of wax), even stone samples with no trace of paint left. This indicated possible, relatively recent oil treatments for stone protection.

This hypothesis was taken into account when critically considering the results of staining tests (and solvent tests) which gave better evidence of the prevalent localisation of oil and proteins and were therefore more useful for identifying paint media.

X-ray fluorescence analysis for phosphorus in some cases confirmed the hypothesis that layers stained by protein stains should contain casein.

SOUTH LATERAL PORTAL

The stratigraphic examination and comparison of the results obtained with different methods of analysis showed that the paint structure of the south portals includes paint layers laid at three different times:

- the first paint is not always present;
- the second paint is extensive; it seems that the sculptures were completely overpainted by covering both the previous paint and areas where it was not present;
- a third repainting or in some places retouching was carried out at a later time; at present most of these retouchings appear to be worn away, probably due to some drastic cleaning when the portals were restored in the last century.

From the analytical results the main characteristics of the painting techniques emerged as follow.

First polychromy

The stone surface stained with the protein stain Amido Black and a tentative explanation is that before being painted, the stone was given a coat of either glue or casein.

Casein was not positively identified as the presence of phosphorus was only occasionally observed by X-ray fluorescence; therefore it cannot be excluded that the protein substance used for coating was animal glue, as suggested by Cennino (4) and the Strasbourg Ms. (5).

After treating the stone with glue or a solution containing casein, a lead white ground was laid; it appears to contain both oil and protein:one possibility is that the medium was an emulsion.

On the contrary, it clearly resulted that the medium of the paint proper is oil.

The range of pigments used is rather limited. In addition to lead white and carbon black, ultramarine blue (lapislazuli) and red ochres occur extensively; verdigris was identified in only one sample.

Red ochres are the only red pigments identified, occurring throughout in flesh paint, clothes, friezes and ground for gilding.

Natural ultramarine is the only blue pigment present, both mixed with lead white and used alone in glazes. The paint of the blue areas showed that it never consists of a single layer: blue robes have an ultramarine glaze over a layer of ultramarine mixed with lead white (fig. a); in the blue backgrounds a layer of ultramarine

mixed with lead white is laid over an underpaint which is black or grey in the lunette (fig. e) and pink in the architrave.

Oil-gilding was used; the gold leaf sticks to a rather thick red ground as detected in Christ's robe, the background of the architrave and the halos of the symbols of the Evangelists. The halos probably had black decorations over gold as some samples from these areas show a black layer over gilding (fig. b).

In addition to gilding, white metal leaf was probably also used for adornments, as indicated by a fragment of it over a red ground observed in a sample from an Angel's robe (fig. c).

Second, possibly complete overpainting

Oil medium and mordant gilding were used as in the previous painting, but the ground for gilding is of a lighter colour as it contains yellow instead of red ochre (fig. b).

Some variations in the pigments used were observed. Ultramarine was substituted by azurite, the only blue pigment identified, often greatly faded.

A greater number of red pigments occurs: in addition to red ochre present in flesh paint and backgrounds, minium (fig. a) and vermilion (fig. c) were identified in samples from clothes.

Verdigris or malachite might have been used, but no green pigment was clearly identified. From the analyses it can only be concluded that a lot of very pale green layers contain a copper pigment: it could be azurite or sometimes a green pigment, but it is not possible to say which kind of pigment it is.

In some areas the overpainting reproduced the original colour (even if with different types of pigments) and also some decorations were remade like the originals, as for instance, the black patterns over gilding in the halos. However frequent changes in colour with respect to the original were observed: some blue clothes were repainted red (fig . a), red backgrounds were repainted blue or green etc.

Some samples from the fillings between the stone slabs were examined. The filling mixture contains lead white and small amounts of minium and brown ochre. From the characteristics of the paint layers above and below the fillings it may be tentatively concluded that these fillings were made at the time of the second overpainting.

Later repaintings

Later retouchings were observed in a number of samples. They are represented by a paint layer directly applied over the previous paint or by a lead white layer, possible ground for a new paint now lost (fig. a).

Surface treatments

In the past the portal probably underwent various treatments, presumably with the purpose of protecting.

The oil treatment, tentatively identified in the other portals, was here rather difficult to detect as the prominent medium of all the paint layers is oil.

The presence of a thin surface film stained by protein stains, frequently covering soot deposits, suggests that it may have resulted from the application of casein. Phosphorus was not identified but this may be due to the very small amount present. On the other hand, casein was recommended in the last century as a consolidant for frescoes (6) and a treatment with casein was presumably carried out on the polychromed sculptures of Ferrara Cathedral (7,8).

But this portal (and also the other ones) presumably underwent a treatment more relevant for its damaging consequences. In fact, natural weathering may not be the only cause of the extreme deterioration of the blue and green copper pigments; a surface treatment may be at least partly responsible.

This hypothesis is also suggested by some azurite layers greatly faded in the lower part and relatively well preserved above. This effect only seems possible if some reacting substance has penetrated under the paint layer through surface cracks.

It should be taken into account that the portals of Bourges Cathedral were restored in the last century (1) when alkali silicates were extensively used in France (9). The application of a silicate solution, with strong alkaline reaction, might be responsible for great damage to azurite and some green pigments possibly present.

NORTH LATERAL PORTAL

The paint covering the sculptures of the north portal is thinner with respect to that of the south portal and seems to have been executed in a single operation: no evidence of overpainting was observed.

The materials and technique of this painting are different from the first painting of the south portal. In particular it appears that:

- A lead white ground was laid on the stone surface, but this was not treated with glue or casein before application of the ground.
- No trace of ultramarine was identified and the only blue pigment used was azurite, now, also here, often very faded (fig. f).

The polychromy of this portal is rather similar to the second overpainting of the south portal; but this similarity does not include the medium which here appears to be casein.

The fillings between the stone slabs showed a different composition with respect to those of the south portal; they contain calcium carbonate and quartz (possibly from sand) but no pigments. From the characteristics of the paint layers above, the fillings seem to date from when the sculptures were painted.

Concerning later treatments, the samples examined do not show the protein film at the surface observed in the samples from the south portal. The north portal presumably did not undergo any casein treatment. However it seems that it was treated with oil and probably with alkali silicate or another reacting substance.

PORTALS OF THE WEST FACADE

The polychromy of the portals in the west façade appears similar to that of the north lateral portal:

- a lead white ground was laid on the stone which had not had a previous protein coating;
- oil is present (probably due to later surface treatment) but the paint medium is casein;
- the only blue pigment used is azurite, now very faded, as in the lateral portals (fig. g).

Moreover, whereas no gilded samples from the north portal were available for examination, it was possible to observe that oil-gilding was used in the portals of the façade and that the gold leaf was applied to a yellow ochre ground similar to that laid on the south portal at the time of the second overpainting.

Another feature indicating similarity between the polychromy of the façade portals and the second overpainting in the south portal concerns the red pigments. In fact, besides red ochres, also vermilion was identified, applied in a thick layer to produce the red lips of a figure (fig; d).

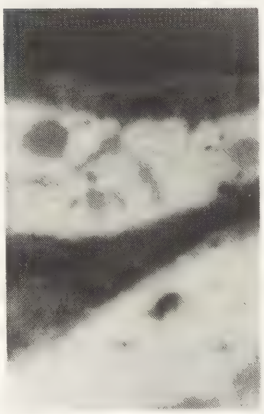
Figures a-g

PHOTOMICROGRAPHS OF PAINT CROSS-SECTIONS, PHOTOGRAPHED BY REFLECTED LIGHT.

Magnification on the printed page 65x (fig.b, 130x). The layers are described in the caption of each paint sample from the bottom layer upward. The approximate thickness of each paint layer is given in nanometers.


a


b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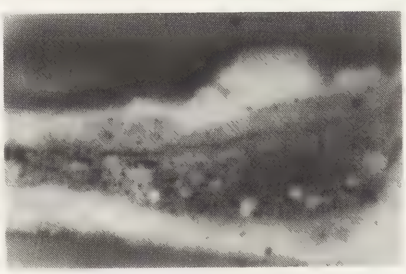
d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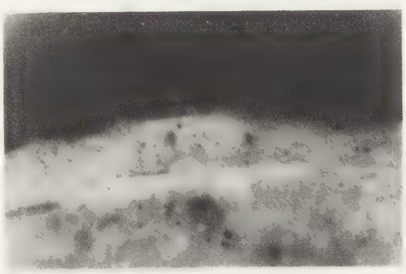
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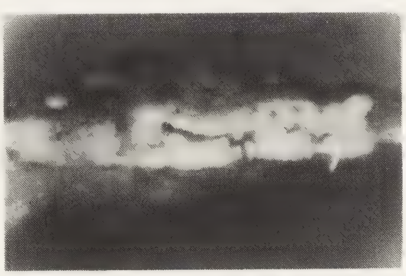
g

a. South portal - Robe of a figure.

1. Lead white ground (trace only on right-hand side of cross-section
2. Ultramarine + lead white (160 nm).
3. Blue layer containing only ultramarine (90 nm).
4. Pale pinkish underpaint: mainly lead white + a few red particles (90 nm); second overpainting.
5. Thin red layer: minium (30 nm).
6. Lead white: presumably underpaint of a third re-painting (120 nm); paint layer above no longer present.

b. South portal - Halo of S. Luca's symbol.

1. Lead white ground.
2. Red ochre + a little lead white: mordant (80 nm).
3. Gold leaf (only on right side of cross-section).
4. Carbon black (only on right-hand side of cross--section); black pattern over gold leaf (30 nm).
5. Lead white underpaint (90 nm);second overpainting.
6. Yellow ochre: mordant (20 nm).
7. Gold leaf (fragmentary).
8. Carbon black: black pattern over gold leaf (10nm).

c. South portal - Robe of the Angel,symbol of S.Matthew.

1. Lead white ground.
2. Red ochre: mordant (20 nm).

(3) (Silver coloured metal leaf missing; present in other fragment of the sample).

4. Carbon black + green copper pigment (possibly verdigris): opaque pattern over metal leaf (50--330 nm).
5. Whitish underpaint, mainly lead white (220 nm); second overpaintig.
6. Vermilion (60 nm).

d. S. Etienne portal, west façade - Lips of a figure.

1. Stone.
2. Lead white ground (20 nm).
3. Vermilion (40 nm).
4. Surface dirt.

e. South portal - Background of the lunette.

1. Lead white ground (100 nm).
2. Carbon black + lead white (70-180 nm).
3. Ultramarine + lead white (80 nm).
4. Lead white underpaint (60 nm); paint layer above no longer present.

f. North portal - Decorative pattern between first and second arch.

1. Stone
2. Lead white ground (only in the centre of cross--section) (30 nm).
3. Very faded azurite (110 nm).

g. Central portal, west façade - Wing of an Angel.

1. Stone (only on left-hand side of cross-section).
2. Lead white ground (only on right-hand side of cross-section) (60 nm).
3. Very faded azurite (70 nm).
4. Surface dirt.

CONCLUSIONS

The results which have emerged from this examination may allow some tentative conclusions if dates and historical information are kept in mind.

The sculptures of the monumental Gothic and Romanesque portals were certainly painted after they had already been set in position. In the present case, this is also confirmed by the observation that the fillings between the slabs are covered by the same paint as is laid over the stone surface.

The sculptures carved in the 12th century were therefore only painted in the following century, when set in the lateral portals of the Gothic Cathedral of Bourges.

When the south portal was built, in 1225, destined to be the main entrance to the church for a certain period, it was immediately painted. It may be that this was intended to be a provisional painting, as suggested by the fact that this first paint is not present in some areas and the fillings between the slabs appear to have been made later on.

If this hypothesis is correct, it points out how necessary it was to have this kind of sculptural cycle painted immediately when it was to be seen by people: the sacred stories depicted in stone had to be coloured.

The north portal, built later and probably not used before the end of the campaign of works, was painted at the same time as the portals of the west façade. Materials and painting technique are similar and show some differences compared with those used some years before when the "provisional" painting of the south portal was carried out. The most notable differences are the use of azurite instead of ultramarine and of casein medium instead of oil medium.

Before the end of this campaign of works on the Gothic cathedral (1255), the south portal was more carefully finished: the fillings between the stone slabs were made and the provisional painting was covered by a new paint, which made it possible to also change the previous colour of some details. This overpainting was probably made some years after (or before) the painting of the other portals, as seems to be indicated by the fact that the same pigments were used but not the same medium, oil being used instead of casein.

The examination of the 13th century polychromed sculptures of Ferrara Cathedral, carried out when very few studies of other similar cases were available, suggested the hypothesis that similarity in painting technique could indicate some connection of authorship(7,8).

The analytical results reported here seem to indicate that this hypothesis must be rejected as various painting techniques and materials were used for painting on stone even in the same place, in a relatively short period of time. In the course of about thirty years, oil painting and casein painting were alternatively carried out in Bourges.

In about the same period, protein medium (probably casein) was used in Lausanne (10) while oil medium was used in Strasbourg (11) and Ferrara (7,8). Moreover, in Ferrara Cathedral, materials and technique similar to those of the polychromed sculptures of the 13th century had already been used a century before for painting the Romanesque portal (12).

It may be tentatively concluded that connections of authorship or date concerning Gothic and Romanesque polychromed stone sculptures cannot be established on the basis of painting technique.

Two characteristics of the polychromy of the Bourges portals can be pointed out.

Firstly, the use of ultramarine blue. This seems rather surprising, but the same pigment was used in Lausanne Cathedral (10) as well as in Ferrara Cathedral for very old repaintings of the porch sculptures.

Secondly, the use of casein medium. This point has already been discussed (7,8). It was observed that casein tempera is quoted as paint medium only in modern times. But antique manuscripts (such as Padua Ms and Marciana Ms) give directions for distempering pigments with milk to be used for fresco painting. Moreover a size made from cheese and lime has been used since very early times, as Theophilus, Cennino, the Strasbourg Ms. and others testify.

The only medium which was quoted for painting on stone (by Eraclius and Cennino) is oil. However the objective results of the present study (in agreement with the results concerning Lausanne Cathedral) appear to indicate that cheese size or milk were actually used for painting on stone.

AKNOWLEDGEMENT - REMERCIEMENTS

Cette étude a été realisée dans le cadre du projet de restauration de la sculpture monumentale de la Cathédrale de Bourges, financée par M. Jenn Conservateur Régional des Monuments Historiques, sous le contrôle de Messieurs Costa et Fonquernie Inspecteurs Généraux, Mme Di Matteo Inspecteur Principal, M. Lebouteux Architecte en Chef.

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Section 7

Waterlogged Wood

Bois gorgés d'eau

UNDERWATER MOLDING OF A CROSS-SECTION OF THE SAN JUAN HULL: RED BAY, LABRADOR, CANADA

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INTRODUCTION

The Basque whaling ship San Juan sank in 10 meters of water on the east coast of Canada in Red Bay, Labrador in the year 1565 (Barkham, 1978; Senior, 1980; Tuck, Grenier, 1981). The hull is constructed of European white oak and remains in remarkably sound condition due to the cold Atlantic waters, -3°c + 10°c (26°F to 50°F).

Our previous underwater work at Parks Canada in 1981 and 1982 using polysulfide rubber flexible molding compounds (FMC) as a medium for recording small archaeological features on ships' timbers of the San Juan (ref. 1 and 2) had shown the usefulness of the technique on a limited scale. However the problem of molding a 1 m by 3.5 m (39" x 11.5') cross-section of the inner hull of a sunken ship necessitated developing a new approach. This paper will outline experimental and field work carried out in 1982 and 1983.

The archaeologist selected a molding site adjacent to the mast step to include the inner hull planking and keelson, providing us with a fairly uniform surface. Some of the surface detail included iron nail holes, trennail holes, tool marks, and wood joins. Fig. 1.

This rubber mold and subsequent epoxy reproduction would be used for interpretive purposes as well as being a permanent record of one portion of the San Juan hull which has been partially dismantled.

1982 PROJECT: LABORATORY EXPERIMENTS

Prior to the field season we conducted a series of experiments at the Parks Canada Conservation Division Headquarters Laboratory.

Our objectives were to find a suitable technique for applying a thin layer of polysulfide rubber over a large surface area and to find an appropriate material for use as a mother mold.

After investigating a number of possibilities we proposed the following:
A layer of polysulfide rubber (Smooth-On FMC 301) would be spread on one side of a piece of burlap, transported underwater on a wooden cradle to the molding site, removed from the cradle and laid face down on the surface of the inner hull and left to cure. Following this, a three-piece reinforced plaster mother mold would be constructed on the back side of the rubber mold.

DESCRIPTION OF MOLDING MATERIALS AND THEIR FUNCTION

Polysulfide Rubber Molding Compound

Smooth-On FMC 301, a thixotropic grade, was selected for its low viscosity and ability to adhere to the burlap, Ref. 3. Based on the surface area to be molded, we estimated that 30 L (8 gal) of rubber would be required to spread a 1.5 cm (.59") layer on the burlap. A slow-cure catalyst was chosen in order to give us the maximum amount of working time as the time required for mixing and spreading of the polysulfide rubber was an unknown factor.

Burlap Backing

The tightly woven jute burlap served as the primary support for the polysulfide which adhered well to its fibrous surface. The burlap was stretched out on the cradle and tacked around the perimeter to the plywood with Monel staples. The dimensions of the burlap sheet were slightly larger than those of the cradle. For handles, two lengths of metal conduit pipe 2.54 cm x 5.18 m (1" x 17') were sewn into the two long sides of the burlap with hemp twine.

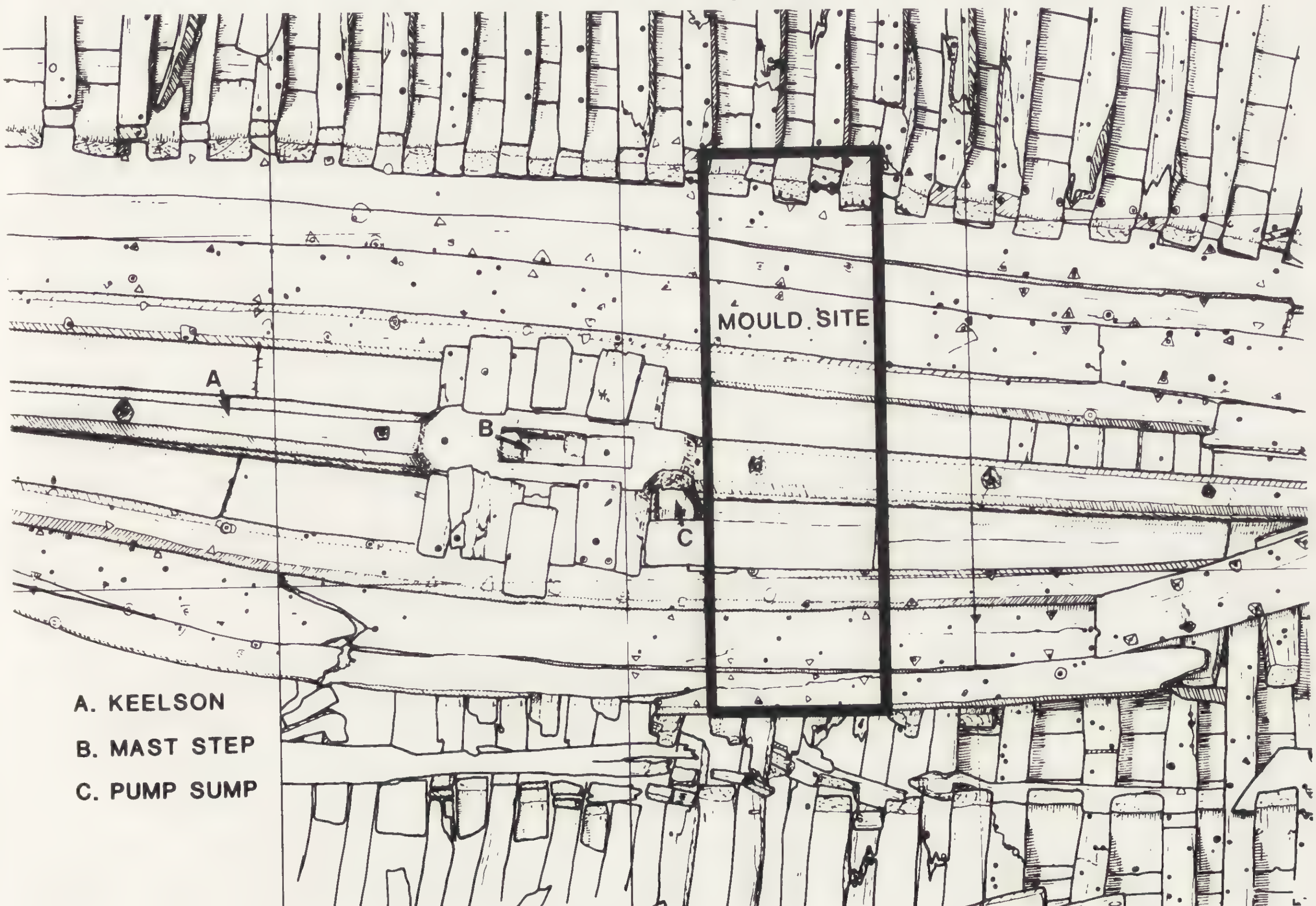

Fig. 1

Cradle for Burlap Backing

This secondary support served two purposes: firstly to facilitate the spreading of the polysulfide rubber on the primary support, the burlap, and secondly to secure the rubber-coated burlap for transport down to the molding site.

The cradle was framed with 5 cm^2 (2" x 2") spruce and sheathed with 1.9 cm (.75") thick fir plywood sheets using galvanized nails. The overall dimensions were 4.3 m x 1.2 m (14' x 48"). Following this, a sheet of 6 mil polyethylene sheeting was secured on the face of the plywood with .9 cm (1/2") Monel tacking staples to prevent any liquid polysulfide rubber penetrating the burlap and sticking to the face of the plywood. A series of 5 cm (2") holes were drilled in the plywood to allow placement of rubber keys on the back of the burlap for relocation of the three piece plaster mother mold. Six lifting slings were attached to facilitate movement with the deck crane and six 11 kg (24 lb) lead weights to achieve negative buoyancy in the water.

Keys

The purpose of the keys on the back side of the burlap as indicated above, was to allow correct rearticulation of the mother and polysulfide molds in the laboratory after removal from the molding site. This would also insure that the correct architectural curvature of the hull, as found, was maintained.

In order to make the keys, the burlap-covered cradle was turned over, fabric side face down. Polysulfide rubber 301 was injected into halved 2.5 cm (1") croffles (hollow polypropylene spheres) and placed on the burlap through the previously cut 5 cm (2") holes in the plywood. Once these hemispherical rubber keys had cured, the croffles were removed. The keys were made before the polysulfide rubber was spread on the face side of the burlap.

Plaster Mother Mold

As previously mentioned, plaster was chosen for the three piece mother mold. After testing various types and combinations of plaster, a mixture of 85 parts Dental Plaster to 15 parts Gauging Plaster was chosen as the most suitable. The addition of 15% Gauging Plaster to the mixture lengthened the working time to 55 minutes. For ease of preparation and handling, the plaster was pre-mixed in 20 kg (44 lb) dry lots, and stored in 30 individual polyethylene bags (6 mil).

Reinforcing the Plaster Mother Mold

Two pieces of expanded metal screening 5 cm mesh (2") were to be used as reinforcement, one on each side of the keelson. Their purpose was both to reinforce the plaster and to minimize the amount of plaster required, thus keeping the weight of each of the three pieces of the mother mold to a minimum. Several eye-bolts were installed onto the screening to facilitate lifting the cured plaster molds using a deck crane.

Sandbags

Weights were required to add sufficient downward weight to the uncured rubber, forcing it to pick up the maximum detail from the wood surface. Sixty canvas bags 15 cm x 41 cm (6" x 16") were half filled with 2.7 kg (6 lb) of beach sand so they would lay flat. The open ends of the bags were folded over and stapled with Monel staples.

1982 PROJECT: MOLDING IN THE FIELD

Preparation of the Underwater Molding Site

1) Elevations of the molding site were taken and recorded by an archeologist.

2) A 10 cm (4") airlift was employed to remove surface debris and sediment from the molding site. Dental tools were used to clean out crevices and cracks in the ship timbers.

3) Sandbags and tool kit were placed adjacent to the molding site.

Polysulfide Mold. Fig. 2

1) Burlap-covered cradle was positioned on the deck of the surface support vessel anchored adjacent to the molding site.

2) Each of the 30 L (8 gal) of FMC-301 liquid rubber and catalyst were mixed with a Jiffy stirrer and an electric drill. The Jiffy stirrer was chosen over a conventional type because it is designed to draw the liquid through the blades producing a more homogenous mixture.

3) The polysulfide rubber was spread on the burlap with hand trowels. Respirators and protective clothing were worn by all workers.

4) Cradle was boomed out over the water and lowered to the molding site using a deck crane.

5) While two divers, one at each end, held the conduit handles apart, a third diver released the burlap which had been tacked to the cradle.

6) The diver at each end then flipped the burlap over so that the rubber was then face down, following this it was manoeuvred over to the molding site.

7) A final inspection of the molding site for extraneous matter was made.

8) The burlap was centered and aligned on the long axis at 90° to the direction of the keelson then lowered so that it touched the top of the keelson only. Both ends were maintained in a horizontal and elevated position.

9) While the divers held the stretched burlap at each end, a third diver cut away the stitching securing half of the burlap to the conduit handles, freeing the burlap on one side of the keelson.

10) The burlap was lowered onto the surface of the hull and conformed to the timbers, keelson outwards. Steps 9 and 10 were repeated for the timbers on the opposite side of the keelson.

11) The conduit handles were removed from the site. We then tamped the entire burlap support against the timbers and recesses in order to eliminate any water pockets.

12) The sandbags were placed uniformly on the surface of the burlap.

13) The rubber was left to cure over-night.

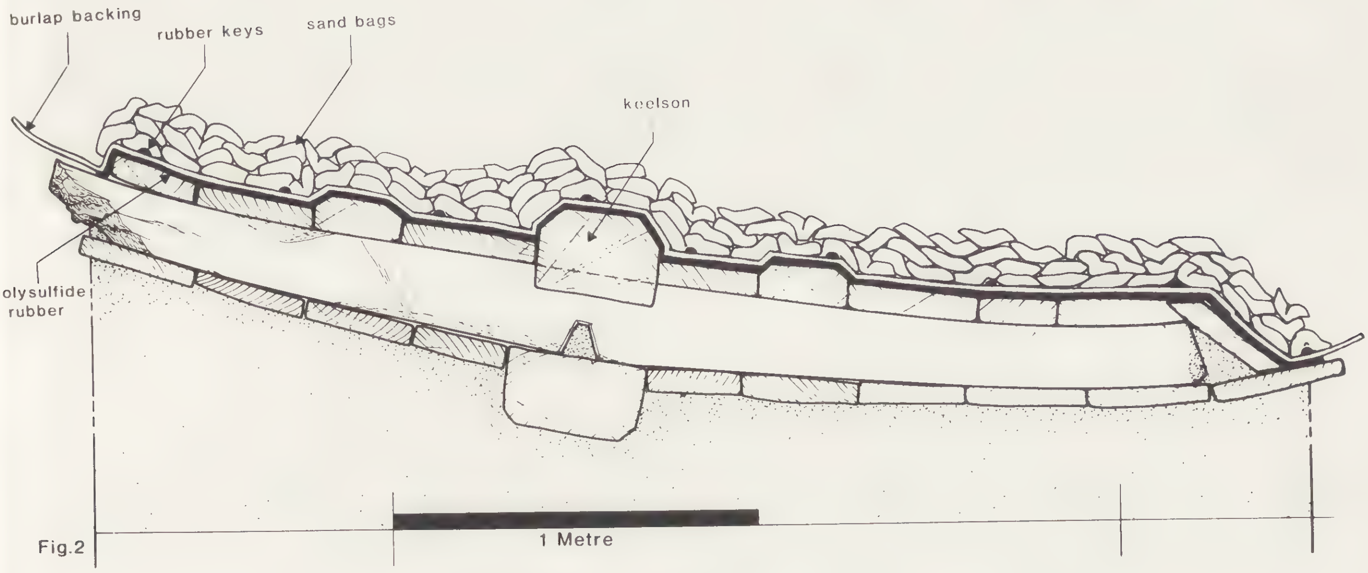

Fig.2

<u>Plaster Mother Mold. Fig. 3</u>

1) The bags of dry plaster mixture and the necessary equipment and two personnel worked in a 6.5 m (21') fiberglass tender (Boston Whaler) moored to the main surface support vessel directly over the molding site.

2) Below, the sandbags were removed from the burlap; a thin film of lithium based grease was applied over the entire surface of the burlap to serve as a release agent.

3) The two pieces of expanded metal screen reinforcement were positioned on the burlap, one on each side of the keelson; the perimeter of burlap was tacked down to the timbers with 1.27. cm (.5") Monel staples to prevent any shifting.

4) Several bags of dry plaster mixture and sea water were prepared in the polyethylene bags using a short length of broom handle and lowered by rope to the molding site.

5) Although we made several changes in the proportion of water to each bag of plaster, the plaster would not set properly but rather continued to disperse in the water when poured from the bag. This was contrary to our previous laboratory experiments and underwater trials. In addition, unused bags of wet plaster took as long as two hours to set, by which time divers became chilled and had to surface.

6) Due to the lack of success with the plaster mixture and not having any additional time to proceed further, we decided to postpone our project until the following field season.

7) We removed the metal screening and the burlap-backed cured polysulfide rubber mold from the site to permit further mapping of the shipwreck by the archaeologists.

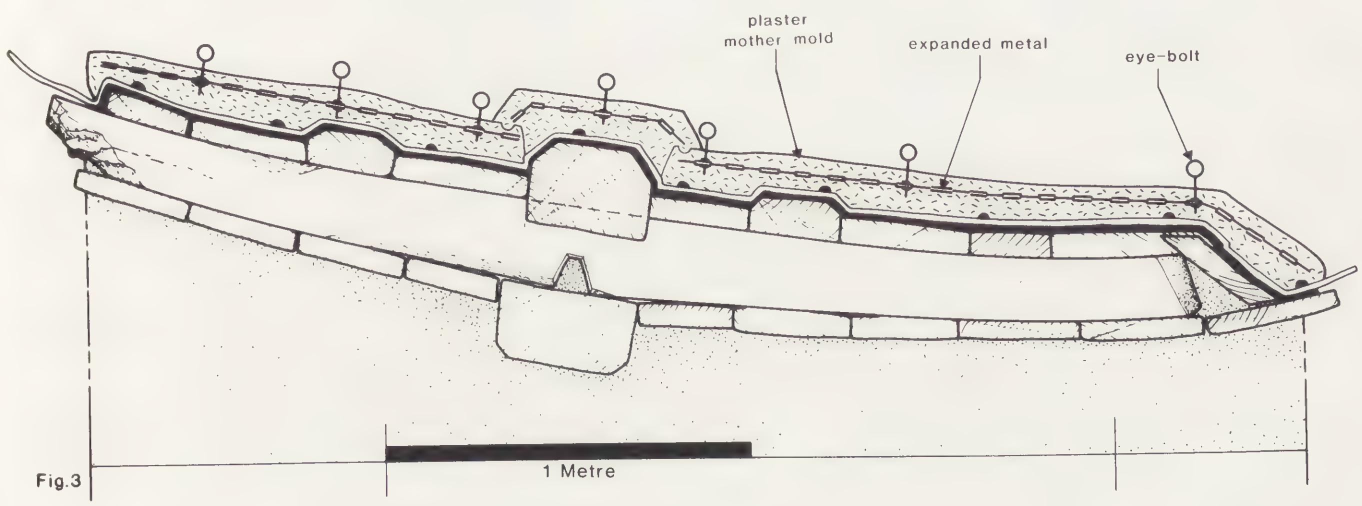

Fig.3

1982 PROJECT: SUMMARY OF FIELD WORK

The first difficulty encountered was the considerable amount of time it took to mix and spread the polysulfide rubber on the burlap. This took the better part of two hours during which time the waiting divers began to chill. Fatigue was also a problem as one of us had to mix and spread the viscous rubber and then put on diving gear just prior to the lowering of the cradle. We therefore thought for the 1983 field season it would be necessary for some of the surface operations to be carried out by additional conservation staff.

Because the mold was not properly weighted due to insufficient quantity of sandbags, the rubber did not record as much detail as expected on the surface of the inner hull. However, those areas pressed into direct contact with the wood did give excellent reproduction.

1983 PROJECT: LABORATORY EXPERIMENTS

Our first requirement was to find a solution to the problems we encountered with the plaster mother mold mixture. In reviewing the process we were probably using A) too much water in the initial mix causing the plaster to disperse uncontrollably; B) an excess of Gauging Plaster, which prevented the plaster from setting fast enough. After carrying out several experiments with various ratios and combinations of water and plaster, we developed the following formula: 8 liters of water (1.7 gal. imp.) added to a mixture of 22.5 kg (49.6 lb) Dental Plaster and 3 kg (6.6 lb) Gauging Plaster. The 8 litres of water was the minimum required to give a butter-like consistency. This mixture allowed easy spreading and did not disperse readily in water.

Since we were now dealing with a much thicker consistency of plaster, we could no longer mix it directly in the polyethylene bags. Therefore mixing of the plaster would have to be carried out in a semi-rigid polyethylene bucket employing an electric drill with a custom made Jiffy type stirrer.

Although we were satisfied with the laboratory results of our plaster experiments, we decided to test the new mixture and its application prior to the 1983 field season in an Ottawa area man made lake. Positive results were obtained.

1983 PROJECT: SUMMARY OF FIELD WORK

We followed essentially the same molding procedure as in the 1982 field trials with the exceptions we made and have noted below.

Polysulfide Mold

Again one piece of rubber-coated burlap was used to mold the 1 m x 3.5 m (39" x 11.5') area. However, for ease of handling and efficiency it would have been preferable to have done the rubber mold in three separate pieces: one covering each side of the hull to the base of the keelson and one covering the keelson section.

Sandbags

We increased the number of sandbags from 60 to 250, twenty of which were filled with 10 kg (22 lb) of lead shot each. The latter would be placed along the base of the keelson on each side, to ensure contact in these recessed areas.

With the additional bags of sand and lead shot which completely covered the molding site, we hoped to sufficiently weight the rubber mold. However, upon removal of the rubber mold at the end of the project we observed that approximately 1/3 of the mold on one side of the keelson had recorded only a limited amount of detail. We concluded that one of three things happened; A) insufficient amount of weight applied to that particular area; B) the polysulfide rubber had commenced to cure before the rubber-coated burlap was set in place and weighted; or C) we did not sufficiently tamp the backside of the rubber mold onto the surface of the wood before the weights were applied.

Plaster Mother Mold

Each batch of mixed plaster was lowered to the bottom by rope and tipped out of the polyethylene pail onto the expanded metal screening. The plaster was then forced through the screening by hand onto the back of the burlap-polysulfide mold and made to stand up to 6.4 cm (2.5") above the top of the screening. The resulting plaster mold was approximately 10 cm (4") thick. The underwater setting time of each batch of plaster was about 55 minutes. This allowed us to make each of the three plaster mold components in one campaign, thereby giving us three separate homogenous plaster blocks. First each side of the keelson was molded and allowed to set, then the keelson was molded. Prior to casting the keelson mold section, several hemispherical keys were cut into the plaster mold along each side of the keelson with a brace and custom made heart shaped bit. A release agent was not required for the three-piece plaster mold, as unset plaster will not bond to set plaster underwater, provided there are no undercuts.

No problems were encountered in the separation of the three-piece mother mold from the polysulfide mold.

After removal and raising of the plaster molds from the site to the deck of the support vessel, the surface was found to be cheese-like in consistency and therefore easily damaged. However, after 6 weeks of air drying, they hardened completely.

SUMMARY

At the end of August both the mother mold and polysulfide mold were raised to the deck, transported 1/2 km (.3 miles) to land and crated for surface shipment 1700 km (1056 miles) to the central laboratory in Ottawa, Ontario. In January-February 1984, Mr. James Lauder fabricated the polyurethane foam-filled reinforced epoxy cast.

Although we were satisfied with the overall results of the molding project, there is still need for improvement if this technique is to become a viable method of recording archaeological ships' features underwater.

FUTURE WORK

The authors have been requested to mold the mast step of an unidentified second galleon in Red Bay, Labrador. As well, we are to develop techniques to facilitate core sampling ship's timbers of white oak both on the surface and underwater.

ACKNOWLEDGEMENTS

We would especially like to thank the following people; Mr. James Lauder of Parks Canada for his invaluable expertise; Mr. Charles R. Senior of the Canadian Conservation Institute; Mr. Thomas Strang, conservation student at Queen's University, Kingston, Ontario.

We would also like to thank the participation of the following Parks Canada Marine Archaeologists; Mr. Denis Pagé, Mr. Peter Waddell, and Mr. Michel Bujold, and Ms. Victoria Jenssen, Head, Wet Sites Conservation Laboratory, Parks Canada, Ottawa, Ontario, and Ms. Catherine Munroe, Conservation student at Queen's University, Kingston, Ontario; Mr. Robert Hellier from Parks Canada Archaeological Research Division.

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ON THE INVESTIGATION OF WATERLOGGED WOOD IN CONNECTION WITH ITS CONSERVATION

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Summary

To express the experience in applying different techniques for waterlogged wood conservation it is necessary to give not only a qualitative description but a quantitative estimate of the results as well. These include indexes of shrinkage and the degree of filling the pores with a conserving substance in every article. When it is impossible to take samples for examination some indirect methods to evaluate the water content and the degree of filling the pores of the wood with a conserving substance are suggested, using the data on weighing the article in the water-saturated state before treatment, then after impregnation with a conserving solution and after drying. Some calculation formulae are given for cases when the conserving substance density is higher than that of water.

By now a considerable number of methods for the conservation of waterlogged wood has been proposed. When choosing the optimal one it is considered necessary to take into account the species of wood and the degree of its degradation which is characterized by changes both in the anatomical structure and the chemical composition of the wood. In hydrolytic conditions degradation leads to the decrease of the cellulose part content and the reduction of its polymerization degree, to some relative increase of the lignin content, to the rise both of the maximum water absorption of the wood and of its shrinkage indexes, and to the lowering of the wood density and mechanical strength.

Unfortunately, it is not always that there is a possibility of receiving all data on the state of every article before its conservation, as it is connected with taking samples from it. The anatomical examination which requires small samples can more often than not be carried out. With its help the species of the wood can be determined and the state of wood characterized to some degree; whereas the chemical analysis of the wood composition is restricted to cases when extracting the fragments necessary for the analysis has no essential effect on the outward appearance of the article and can be compensated by restoratory fillings. Even the estimation of the water content which is recognized as one of the basic and necessary ones for the formation of an opinion on the degree of the wood degradation proves impossible for small articles of considerable historic and artistic value, as it requires extracting and drying the fragments. That is why, it is often the experience and intuition of the restorer that play a decisive part in making a choice of the conservation method to be used. Within the limits of this experience, it is very important to employ simple non-destructive methods helping to estimate the treatment effectiveness.

In this connection, the fixation of the shape and dimensions of the article before treatment and the determination of its volume seems to be an essential part of the work. The shape of the article in the main projections can be fixed by tracing it on square-rule paper, with marking the directions of the fibres - longitudinal, radial and tangential. The volume of the article can often be taken as the sum of volumes of a regular shape and calculated by the parameters measured. With such measurements and calculations after conservation it is possible to estimate the indexes of the linear and volumetrical shrinkage. Together with the information on the presence or absence of any signs of warping and crackings, these data are characteristic of the treatment result. Basing on the result of weighing the article before treatment in the water saturated state (m_1), after impregnation with a conserving solution (m_2) and after drying (m_3), we also apply some methods for indirect estimation of the maximum water absorption of the wood and the percentage of the pores filled with the conserving substance. If the density of the conserving substance is d_c (g/cm^3) higher than that of water (d_{H_2O}), by solving the three-equation system it is possible to estimate the weight of the dry wood (m_o), the volume of the pores filled with water (v_o), the maximum water absorption - absolute ($W=\frac{d_{H_2O}\cdot v_o}{m_o}$) or relative ($W'=\frac{d_{H_2O}\cdot v_o}{m_1}$); the volume of the conserving substance (v_c) and, correspondingly, the degree of its filling the pores volume previously filled with water

($N=\frac{v_c}{v_o}\cdot 100\ \%$).

Indeed,

$$m_1 = m_o + d_{H_2O}\cdot v_o$$
$$m_2 = m_c + d_{H_2O}\cdot(v_o - v_c) + d_c\cdot v_c$$
$$m_3 = m_o + d_c\cdot v_c$$

Whence, considering d_{H_2O} = I, we receive

$$v_c = \frac{m_2 - m_1}{d_c - 1}$$
$$m_o = m_3 - d_c\cdot v_c = m_3 - \frac{(m_2-m_1)\cdot d_c}{d_c - 1}$$
$$v_o = m_1 - m_o = \frac{m_3 - m_1 + (m_2 - m_3)\cdot d_c}{d_c - 1}$$
$$W = \frac{v_o}{m_o} = 100\% = \frac{m_3 - m_1 + (m_2 - m_3)d_c}{m_3(d_c - 1) - (m_2 - m_1)d_c}\cdot 100\%$$
$$W' = \frac{v_o}{m_1}\ 100\% = \frac{m_3 - m_1 + (m_2 - m_3)d_c}{m_1(d_c - 1)}\cdot 100\%$$
$$N = \frac{v_c}{v_o}\ 100\% = \frac{m_2 - m_1}{m_3 - m_1 + (m_2 - m_3)\cdot d_c}\cdot 100\%$$

If the water content in the wood is determined before treatment by drying the fragment, the degree of replacement the pores with a conserving substance is estimated on the ground of two weighings (m_1 and m_3):

$$v_c = \frac{W'\cdot m_1}{100}$$
$$m_c = \frac{100 - W'}{100}\ m_1$$
$$v_c = \frac{m_3 - m_o}{d_c}$$

$$N = \frac{100 m_2 - (100 - w') m_1}{w' \cdot m_1 \cdot d_c} \cdot 100\%$$

We applied these calculations to estimate the results of the treatment with polyethylene glycols (I) and oligomers of ester type (2).

When the article's volume (v) is determined, the density of the wood $\left(\frac{m_0}{v}\right)$ and its change after treatment can also be calculated. It should be noted that the weighing of wood in the dry state is carried out after it is subjected to conditioning under a given value of the relative air humidity. Therefore, the value calculated will correspond not to the absolutely dry state of the wood, but to its state under this humidity value

The accumulation of the data like these fixes the experience of the restorer, enables him to make conclusions on how the treatment results are affected by the degradation degree, the species of wood, as well as the size of the object, its shape, the part of the trunk used, etc.

Among the methods of the chemical analysis of the wood composition with the aim to determine the degree of its degradation, rather promising seems the development of the micromethods of the lignin quantitative analysis, as well as of the methods of the cellulose polymerization degree estimation. The estimation of the degree of the wood degradation according to the hardness indexes appears to deserve some wider introduction and study (3,4).

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ADVANCES IN THE CONSERVATION OF WATERLOGGED WOOD 1981-1984

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Summary

The Progress of the Conservation of Waterlogged wood in the period 1981 to 1984 is briefly reviewed. The most notable event was the raising of the Tudor warship Mary Rose, off the south coast of England. This marked the appearance of probably the largest scale conservation project involving waterlogged wood treatment since the Wasa was raised in Sweden twenty years ago.

The Working Group is growing rapidly and continues to sponsor special conferences and publications. The Newsletter continues to be published.

General

The Working Group on Waterlogged Wood continues to be very active, and interest in the topic of waterlogged wood conservation is developing. Special conferences were held in Ottawa in 1981 and in Grenoble in 1984.

The circulation of the newsletter has grown to 700 and it is sent to people in 66 countries. The greatest increase in circulation has been in the U.S.A. A grant from the Canadian Commission for UNESCO was received to help publication and circulation costs and this is gratefully acknowledged. In view of the appearance of the ICOM Committee for Conservation's own newsletter, the Working Group should consider whether continuation of its own specific Newsletter is a worth while venture, and members of the Working Group will be consulted as to their opinion at the Copenhagen meeting.

The rapid development in the field is shown by the size of the bibliography herein, in which 78 papers are referred to.

Large Projects

On 11th October, 1982, the hull of the Mary Rose, a wooden Tudor warship (approximately 440 years old), was raised from the ocean floor just off the south coast of England by Portsmouth Harbour. A very large conservation laboratory had been already been established for treating the small finds from the wreck, but the commencement of the reconstruction and PEG spray treatment of the hull certainly makes this project the largest in scale and most ambitious since the Wasa was raised twenty years ago. We are all watching the project with interest and looking forward to hearing about the progress of treatment.[12,54]

There have also been some other very significant events relating to the conservation of shipwrecks:-

In Marseilles, France, the conservation by freeze-drying at atmospheric pressure of the hull of a Roman ship has been completed.[21]

In Belgium, the conservation of three Roman ships from Pommerouel with a traditional PEG method has been reported to be completed, successfully.

In Canada, a section of a 17th century French ship, the Machault has been successfully conserved with PEG & spraying.[55]

Other notable shipwrecks in the process of treatment include the Bremen Cog at the Schiffharts Museum in Bremerhaven, West Germany, the Brown's Ferry Vessel at the University of South Carolina, U.S.A.,[36,62] the bow section of the New York City "Ronson wreck" (a 16th century sailing ship) in Groton, Massachussetts, U.S.A.* and the Shin-An treasure ship in South Korea[21].

In Canada, large scale underwater moulding and casting of an entire hull section of a shipwreck (The San Juan at Red Bay, Labrador) has been carried out[17,58,59,63].

Terrestrial projects in which large scale conservation of waterlogged wood have been carried out include, the Jorvik excavations in Coppergate, York, England[78], the Somerset Levels project, Somerset, England[67,68,70,71], the Hoko river project in Washington State, U.S.A.[78], and the excavations by Memorial University, St. Johns, Newfoundland of a Basque whaling station at Red Bay, Labrador[77].

Technical Innovation and Research

In regard to the development of equipment, the use by Drocourt and Morel-Deledalle of an atmospheric freeze-drying unit capable of freeze-drying entire ship, is a most significant step forward[21].

Another important new technique is the method of underwater casting and moulding for recording ships features which has been developed by Murdock and Daley of Parks Canada[17,58,59].

Sugars as alternatives to PEG are gaining increasing use as impregnants and pre-treatments for freeze-drying. Useful work on sucrose has been carried out by Parrent in Texas, U.S.A. and by Grosso in Washington State, U.S.A.[44,41], on mannitol by Barbour in Seattle, Washington State, U.S.A. and by Murray in Portsmouth*, England* and on sorbitol in comparison to the above sugars by Grattan and Cook at the Canadian Conservation Institute in Ottawa, Canada*.

As for PEG, the possibilities and permutations of its use continue to expand. Watson of the Ancient Monuments Laboratory in London, England proposed the use of mixtures of high and low molecular weight grades as a pre-treatment for freeze-drying very deteriorated British hardwoods[50]. This appears to be a promising approach.

Another significant development with PEG was the analytical method of Young and Wainwright to determine cell wall penetration[37].

Our understanding of the nature of waterlogged wood continues to develop and important contributions have been made in this respect by Florian, Hoffman and Jagels[27,28,29,30].

Several workers, in particular Jespersen, have demonstrated that the use of TEOS (tetra ethyl ortho silicate) is better avoided as a treatment for waterlogged wood[42,16].

The freeze-drying process continues to be better understood and a remarkable contribution to this understanding has been provided by Till[46].

* Unpublished.

The effects of air-drying on very deteriorated waterlogged wood has been carefully studied by Barbour, who has shed much light on the behaviour and processes which take place. Barbour is also responsible for providing us with a proper terminology for dimensional behaviour during drying[5,18].

Comparative and collaborative projects continue to be generally regarded as being of key importance to the better understanding of the treatment of waterlogged wood. Schweingruber in Switzerland, Sawada in Japan and Grattan in Canada have all proposed that inter-laboratory studies similar to, or based on, the Braeker and Bill or Grattan type of approaches be extended to laboratories in several countries[13,16,7]. A proposal based on these suggestions has been circulated to members of the Working Group and will be discussed at this meeting. At the time of writing, there has been a generally favourable response to this proposal and many people have indicated a willingness to participate.

Final Remarks

In the three years in which I have been Coordinator of the Working Group the most important thing I have learnt is that there is a great desire within the archaeological and archaeological conservation professions, in many countries, for more interchange of ideas and opinions and better access to information. The success of this Working Group has largely been due to the fact that it has been able to help fill that need. As a consequence, the Group has also been able to fulfill the mandate given to us by the Committee for Conservation; that of communicating information about conservation to other related professional groups such as museum personnel or archaeologists. This is simply because those who have a professional interest in waterlogged wood, shipwreck conservation, or wet-site conservation have subscribed to our publications or attended our special conferences. It should be added that most non-conservators involved have indicated that they would not be interested in attending a general conference on conservation. There is no doubt in my mind that we should continue to cultivate the dialogue which has been established, but this poses some problems. To develop this group further, special conferences, publications and the Newsletter must continue to be produced, but the Working Group has very limited resources. Furthermore, I think it is questionable whether there is wisdom in developing an international conservation organization dealing solely with one material in one type of condition!

I confess that I don't have a solution to these problems which can best be described as growing pains, however, I would like to propose to this Working Group and to the Coordinators and members of other Working Groups dealing with or interested in archaeological conservation that in the next three years, we consider the possibility of reforming ourselves with some other interested working groups as a Working Group or perhaps a subcommittee for Archaeological, or perhaps Wet-Site and Shipwreck Conservation?

If a more comprehensive Group could be formed, perhaps there could be a greater division of responsibilities amongst the members, which would increase our resources and at the same time, better fulfill the needs of the archaeological community.

Acknowledgements

I gratefully acknowledge the material support that the Canadian Conservation Institute has given me in acting as Coordinator of this Working Group. I also must express thanks to Cliff McCawley for his continuing support and advice and to other colleagues who have given me much help, and in particular I would like to mention Gregory Young.

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CONSERVATION OF ARCHAEOLOGICAL WOOD : A SYSTEMATIC CLASSIFICATION OF CASES

(A preliminary study in methodology)

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Stockholm-Warsaw .

SUMMARY

Described is a simple system for preliminary classification of individual cases into groups of common technical parameters and for connecting this with equally classified relevant technical matters.This is very helpful in the search for information necessary in a rational programming of treatment and in formulating directives for research.The system is,practically,applicable to all kinds of cases.It is working through interrelated consequent steps.A brief introduction in the basic idea is followed with a few examples of application and some comments.

GENERAL INTRODUCTION

From earliest times in the history of mankind wood was the most popular material for producing almost everything,from very small objects to very large constructions.Some of this survived until now,but time,conditions of survival and many other specific factors caused a more or less advanced degradation of the wood material and cell structure,leading in turn to radical changes of properties.

The main work in conservation is to stabilize,consolidate and protect the wood substance from further degradation.The main purpose of conservation is to treat the object as document from the past and the evidence it brings. There is a lot of specific factors involved here.

But the procedures of direct treatment are only a part of the whole process of preservation of archaeological wood objects.Before this come all matters of exposure,primary protection,lifting,transport,etc., and after conservation there are problems of properly arranged future and protection.And from the beginning to the end ,continuously,are questions concerning the available facilities,funds and properly trained staff /1/,not mentioning time.

Taken together,all these factors,facts and situations make the c a s e .They are participating in conservation problems in different degrees,in dependence of circumstances, making each case practically unique ,as concerns the total of basic parameters,factors and requirements.

This abundance of individual elements does not help in a consequent and planned development of the conservation procedure.The particular technical information is fragmentary, dispersed,often difficult to find inbetween other written material,etc. In the presented paper there is a proposal for a classification system connecting classified groups of cases with classified information through interrelated consequent cross references.

THE CLASSIFICATION OF CASES

The first step in the system is to divide cases into groups of approximately similar basic parameters, with the help of the enclosed diagram.The classification starts at the top of the diagram,with the first differentiation based on the s t a t e of wood in the object This,generally,may be GOOD or BAD.Inbetween may be the MEDIUM,partly belonging to the good (optimistic) side and partly to the bad (pessimistic) one.It is included in one of them.This is not a very precise differentiation,but it helps to divide cases into such where the condition of wood calls for very specific,often extremely difficult,operations, and these where treatment will be more of a "routine" kind.

From here classification proceeds in the vertical direction,across further horizontal lines.So,in the second horizontal line the above two groups are divided,each,into three next cathegories according to the s i z e of the object.The assumption here is that small items have a chance to be treated in a well organized laboratory with all facilities and experienced staff available,whereas larger objects will need a hall with permanent or occasional installations and equipment of basically different kind.There will be different kinds of manipulations ,larger amounts of materials, bigger tanks,problems of ventilation,of transport,supports,safety measures,etc.

Oversize objects present a much more complicated combination of problems,not only directly concerning treatment but also matters of planning,organization,protection,with a lot of initiative and creative thinking,all additionally depending on time and financial possibilities.

But not always a small object will be treated in a laboratory or a large one in the hall or outside.Small objects may have to be treated in the field,and the large ones divided into smaller fragments may go to the laboratory.So,in the third horizontal line the six already present groups are further divided, each,into three more possibilities according to the p l a c e o f t r e a t m e n t .

From there the classification line goes straight down and lands in a numbered "box"in one of the horizontal rows ,in the first one for waterlogged wood (WL), in the second for wet wood (W),or in the third one for dry wood, (D).The distinction here is not very sharp,but in case of doubt two neighbouring numbers can be attributed to the questionable case.

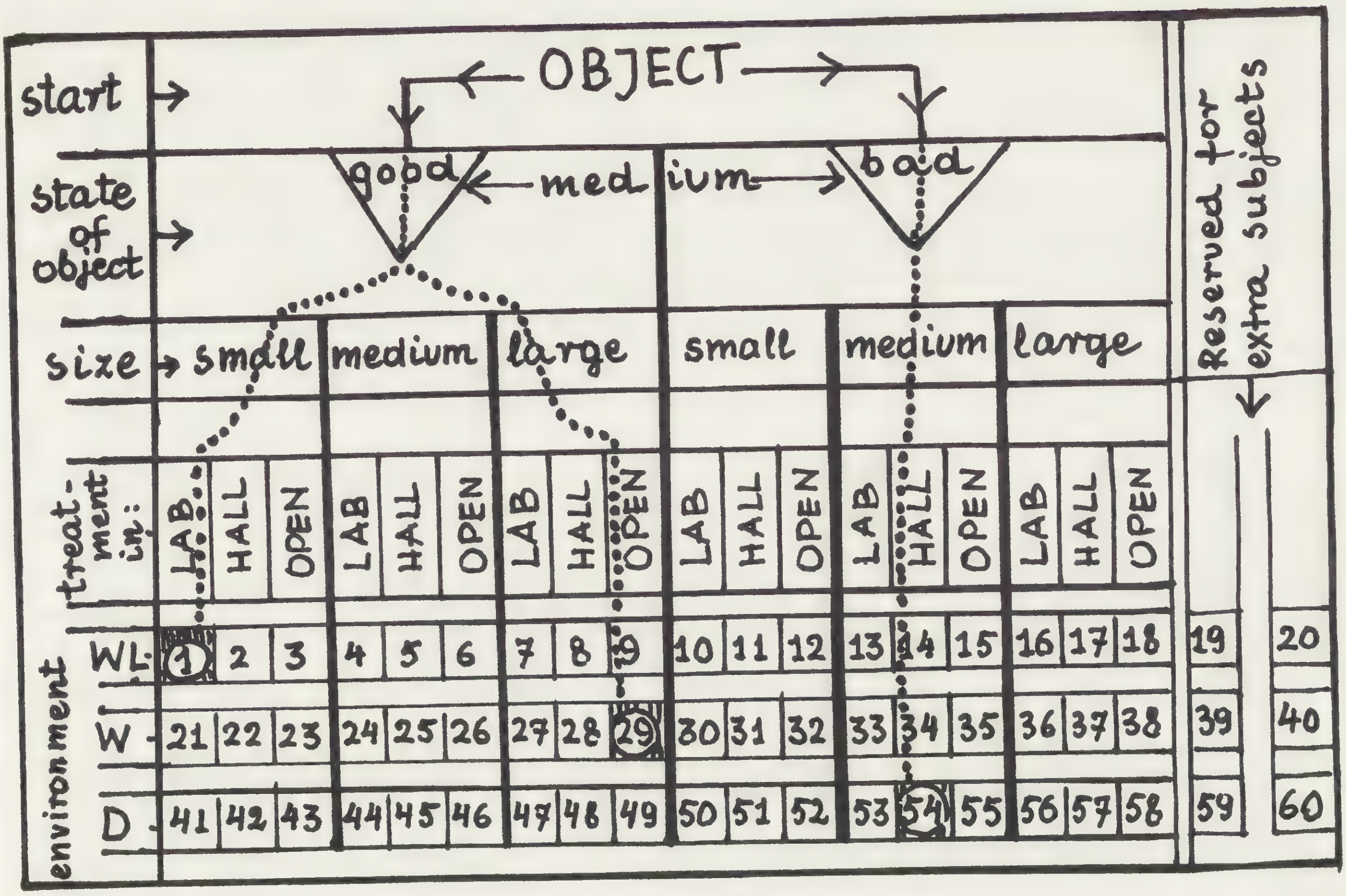
In this way cases are divided into groups having similar working conditions.For example a small waterlogged object in good condition, treated in the laboratory will belong to box 1, but a large wet object in good condition, treated in the field will be placed in box 29, and a medium size dry object treated in the hall lands in box 54 (see diagram).

THE CLASSIFICATION OF TECHNICAL FACTORS

The technical factors in procedures of conservation are tied as well with direct treatment of objects as with all other matters resulting from particular circumstances.They may be divided into groups,as follows:

/a/ factors connected with the environment, the "conditions of survival",the kind of soil, the kind of water,atmospheric conditions,temperature ,humidity,acidity,biologically active factors,etc.,and their influence on the condition of archaeological wood.Exceptionally,also ice as milieu for preservation,and relevant factors, enter here,

/b/ factors connected with all kinds of investigations,starting with the examination of the kind of wood and its state of degradation,the "geography" of damages and destruction and the diagnosis of the general requirements,and also matters of analyses,research ,testing of new methods,materials and procedures,introducing new techniques in photography and recording,



THE CLASSIFICATION OF CASES.

/c/ factors connected with operations preceding the proper treatment,such as exposure of the object and lifting,preliminary protection, supports,transport,measurements,moulding,casting,temporary storage,etc.,

/d/ factors associated with all technical problems in the direct treatment of conservation,including products,methods and technique of work in dependence on the state and kind of object, and also with the organization of the working place (laboratory,hall,open space),properly trained staff,matters of personal safety,tools,containers,machines,etc.,

/e/ factors connected with proper care and protection of the object after treatment,including packing,transport,storage,display,regular survey of state,instruction for caretakers,proper supports,safety measures,etc.

/f/ additional factors connected with exceptional kinds of cases such as objects with carved and (or) painted surface,combinations of wood with other materials,whole settlements,etc.

These six basic groups of factors may further be divided into many subgroups,according to wishes and needs,but also this has to be done according to a systematic regular scheme.
The next step now will be to connect these classified technical factors to previously classified cases.

CONNECTING TECHNICAL FACTORS AND CASES

Quite obviously n o t a l l technical factors listed above are equally participating in the problems of particular groups. For each group of cases it is necessary to select from the above given full list only relevant factors.The most convenient way to do it is with the help of a ring-bound loose-leaf system.The particular cards are receiving numbers corresponding to "box numbers" in the classification of cases, and only factors belonging to the group are listed there ,with eventual brief comments, in the same order as used in the general classification.
As can be expected not one but several cards will be needed here for each number,and the loose-leaf system will easily accomodate all kinds of revisions,additions,replacements, rearrangements,etc. In this way the different kinds of cases,together with problems,factors, situations,requirements,etc. become arranged in a systematic order.It gives a good general introduction into the complexity of interrelated factors in the field of archaeological wood objects.
In turn,it is necessary to connect all this with a possibly comprehensive assortment of information on technical details connected with methods,products,tools,installations,materials,etc.,all gathered together in a kind of c a t a l o g u e .

THE CATALOGUE

This again has to be in a loose-leaf ring-bound form.It is simply an organized collection of information on particular relevant subjects,in a way consistent with the classification of cases and factors.
The information for the catalogue can not be filed in a single operation.It has to be gradually built up,as it comes,often unexpectedly.It is collected from many possible sour-

ces (publications,textbooks,scientific reports journals,personal practice,conservation reports,observations,etc.,etc.).It can be picked up anywhere,but on only one absolutely obligatory condition: each entry must concern only a single particular subject.It should not be given as a composite "mélange" of different technical informations all together,even when they concern the same case, as most often happens in reports and publications.

Such composite texts have to be "dismembered" into particular single subjects,and each information must be filed in its respective place,without unnecessary trimmings,and without the company of other subjects.For example a selective differentiation has to be made in collective works,such as materials from congresses,where very valuable bits of information are totally dispersed in the amount and variety of presented material/3/.In this way we receive information well "concentrated" on individual subjects.

The catalogue is now ready to be connected, by a proper system of cross-references,with classified factors and,through them,with particular groups of cases or,vice versa ,starting from cases,through classified factors one may come to needed information.Sometimes, some subjects may have a lot of information filed in the respective card,which may mean that the particular subject receives much attention from specialists (or the person collecting information has preferences...),whereas a lack of information in other places may mean,that not enough attention was paid to the particular subject (or that it is insufficiently explored and needs further research).

For reason of space and clarity the volume of information in the catalogue (except very brief items) is to be reduced to essentials only (a kind of comprehensive abstract),with due bibliographic reference to the original source. These references are preferably collected in another,separate,ring-bound volume. It is practical to provide these bibliographic notes with back-references to positions in the catalogue.

COMMENTS and EXAMPLES

The described system of standarized classification may at first seem to be rather artificial and complicated, and of questionable usefulness. But it is well worth trying ,though some kind of accomodation to the standarized principles may take some time.

A few comments may be added to the already presented material:

/1/ a question may be asked for w h o m this rather elaborate "classification" is expected to be of help? The answer is simple: for people that will know how to use it. Can be single persons,institutions,specialized libraries,specialized laboratories,scientists, conservators,etc.,

/2/ here come next questions: what are the arguments f o r the proposed system,and w h e n is it really helpful ?

There are many arguments here. The well known problem of "where have I seen some time ago this information about ..." can be greatly reduced grace to the Catalogue. When keeping to the basic standard for classification of cases and factors,and for proper cross-references it becomes more easy to compare one's own experience and information with other people's.For example one may ask :"...please,tell me what information do you have under Nr.37a on the influence of environmental factors in case of badly preserved large objects in wet condition,that are going to be treated in a hall?..".And classified information will just come answering this particular problem.

/3/ as concerns details in the organization of the collected material there can be a large amount of freedom in individual solutions, provided that the basic standarized scheme is fully respected,it should not be "adjusted",

/4/ the ring-bound system makes the work much easier, with all possibilities of accomodating revisions,additions,changes,etc.

/5/ the next question will be how the beginner should start his work ? The first condition is that he must be a specialist in the field.It also is good when this person has already had some problems in finding (or in"fishing"for) the needed information.This gives proper motivation for making things easier,

/6/ it is best to start the work on a very modest level,for one case or one problem only and gradually enlarge the covered field.The person doing it ,preferably,should have a natural inclination towards collecting as a hobby and give kind attention to problems of waterlogged wood, and be orderly and systematic by nature.

/7/ as concerns filing,it has to be done at the moments of finding the information,and not left for "later on". This simply may mean n e v e r .

/8/ sometimes very small bits of information useful for problems of archaeological wood may be found in a text completely irrelevant to matters of conservation,or just only very slightly connected with that matter;as example of this may be the problem of pentachloro phenol,popularly used as a very effective disinfectant but now supposed to be greatly accelerating the decomposition of wood /2/.

/9/ the division of objects and factors into groups is far from precise.For the moment it serves its purpose as concerns classification because,anyway there are neither universal methods nor identical cases ,so everything is just an approximate average.But this is almost sufficient as concerns the similarity of basic parameters,

/10/ as concerns terminology,it might be good to formulate a clear definition what is being understood as waterlogged,and what as wet, eventually dry,wood.There seems to be a great individual variety in classification here. This in turn may find repercussions in the classification of cases into numbered "boxes".

/11/ the operative program in the presented system can be in a way compared to the chain of reversible chemical reactions.It has to work smoothly and effectively.Eventually,it may bear a distant analogy to a hand-computer or to a slot-machine, with a basic exception: the two mentioned machines are not reversible.

/12/ to illustrate the possibilities of the system a few simple examples may be given:

- if anybody wants to get collective information on e v e r y t h i n g concerning waterlogged wood he should consult cards (boxes) from 1 to 18 (evtl.19,20) for general presentation of factors, and from there,according to needs, or interests,go further to the catalogue,
- if there is difficulty in attributing an object to the waterlogged (WL) or wet (W) group- the simplest way is to take the two

cases $\rightleftarrows$ factors $\rightleftarrows$ catalogue $\rightleftarrows$ bibliography.

neighbouring numbers (boxes) and look for information in boths,to find what really will be applicable,
- some additional factors for specific cases, such as polychrome wood ,whole settlements, etc. will be included in the last two vertical rows of boxes,and accordingly have separate cards in the classified factors.

/13/ it is quite logical that such a system of organized classification will be also good for other objects,e.g. textiles,metals,paper, etc. of course in different arrangements.

/14/ there is one more factor that should be included in the "specific" group,and it is not a purely technical factor: it concerns ethical principles in respect to all kinds of operations,decisions,treatment,etc. The basic idea of these principles is to give maximum attention and efforts to the preservation of the object as a document of history.An authentic document! These principles should also be included in all purely technical considerations and find their place in the catalogue.

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/1/Gerald H.Grosso.After excavation,then what? in "Occasional Papers in Method and Theory in California Archaeology",No.2,Nov.1978, 1-6.

It is an excellent review showing the multitude and diversity of factors ,and the responsibilities in the procedures of conservation.

/2/William C.Feist. Weathering of wood in structural uses, in "Structural Use of Wood in adverse Environments",proceedings of a Symposium, Vancouver 1978, 156-178.

On page 177 ,in the discussion between R.S. Smith and W.C.Feist a very important observation is communicated,namely that pentachlorophenol (commonly used as effective disinfectant) is supposed to greatly accelerate the weathering of treated wood.A good example of a fragment of important information hidden in a text on other subjects.

/3/ David W.Grattan (Editor), Proceedings of the ICOM Waterlogged Wood Working Group Conference, Ottawa 1981. 292 pages.

An excellent source of information that could be divided into "single element" factors for the annotated Catalogue.

CONSERVATION OF WATERLOGGED ORGANIC MATERIALS: COMMENTS ON THE ANALYSIS OF POLYETHYLENE GLYCOL AND THE TREATMENT OF LEATHER AND ROPE

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PART I BATAVIA TIMBERS: AN UPDATE

Since 1976 a large section of ships timbers from the wreck of the *Batavia* (1629) has been undergoing treatment in Polyethylene Glycol 1500 at the Conservation Laboratories of the Western Australian Museum. In order to follow the progress of the treatment it is useful to know the extent of the polyethylene glycol penetration.

The use of infrared spectroscopy in the quantitative analysis of polyethylene glycol was first suggested in 1981 by Dr. J.T.T. Pang (Pang, 1981) who has since left the W.A. Maritime Museum.

Unfortunately, Dr. Pang left behind insufficient information for us to properly assess his work in this particular area and we were therefore obliged to start our investigation virtually from scratch.

The Analysis

Effective use of infrared spectroscopy in quantitative analysis (Afremow et al, 1961) requires the elimination of a number of possible sources of error which would not normally be considered in qualitative analysis. A scanning speed must be selected which will allow the instrument to accurately record the true intensity of an absorption band. This speed is determined by scanning at successively slower speeds until there is no further increase in the recorded band intensity; in this particular analysis a speed of $3800cm^{-1}$ (from 200 to $4000cm^{-1}$) per hour was found to be satisfactory.

Background absorption was compensated for by using a reference as close as possible in composition to the sample, in this case by using a reference cell (optically matched to the 0.2mm path length sample cell) filled with benzene, the solvent used in the PEG extraction stage.

In practice it is not necessary to record the entire spectrum of each sample and two smaller scanning ranges were chosen, namely $1000\text{-}1250cm^{-1}$ and $2650\text{-}3050cm^{-1}$. These ranges include the two largest absorption peaks (Pang, 1981), the $1105cm^{-1}$ symmetrical ether carbon-oxygen-carbon bond stretch and the $2870cm^{-1}$ asymmetrical methylene carbon-hydrogen bond stretch, and the limits were chosen so that the lower limit of each range lies on an area of relatively low and constant absorption to enable consistent adjustment of the zero absorbance position for the machine and the upper limit allows the recording of the entire peak so that the baseline can be more accurately determined (using the tangent line technique).

The instrument used was the SP2000 spectrophotometer at Murdoch University and all spectra were recorded in the linear absorbance mode which enables direct measurement of peak absorbance.

Results and Discussion

Fifteen standard polyethylene glycol solutions in benzene (caution - benzene is highly carcinogenic and should only be used under the supervision of a qualified chemist), covering a range of concentrations (5×10^{-3} g/ml to 25×10^{-3} g/ml) and molecular weights (200 to 6000) were made up and their spectra recorded under the conditions outlined above. The concentration range covers all PEG concentrations possible where core samples (max 200mg) are extracted in 10ml of benzene. These spectra were analysed by plotting both peak height (which assumes Gaussian peak shape) and peak area (integrated intensities method) against concentration. It should be noted that while peak height data may not be transferable to another spectrophotometer, the integrated intensities data should be so transferable. The results are shown in Figs. 1 and 2 below and can be summarised as follows.

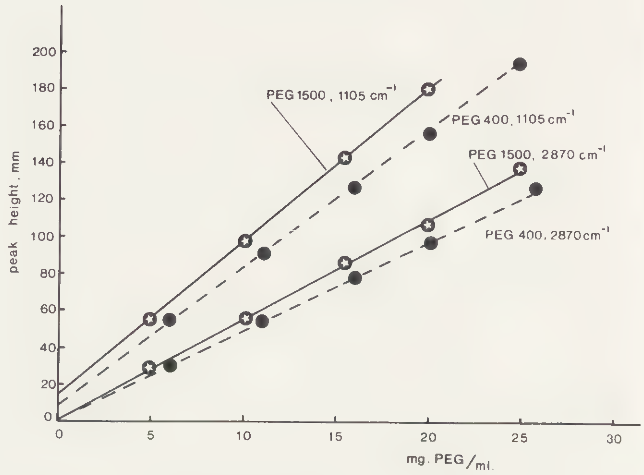

Figure 1. Peak height versus concentration. For the SP2000 Spectrophotometer absorbance = peak height (in mm) $\times 5 \times 10^{-3}$.
For details - Appendix I.

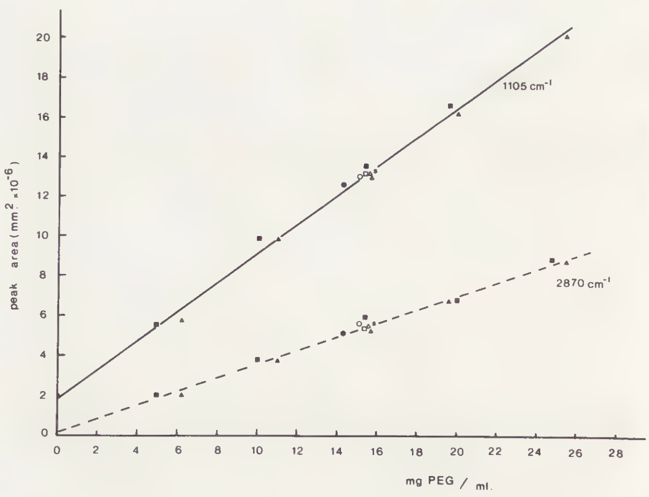

Figure 2. Peak area versus concentration.
△ PEG 200; ▲ PEG 400; □ PEG 600;
$ PEG 800; ■ PEG 1500; ● PEG 4000;
○ PEG 6000.
For details - Appendix I.

The different results obtained by using both peak height and peak area as measures of absorbance are related to the peak shape. In the higher molecular weight PEGs, the absorption peaks are sharply defined while in the lower molecular weight PEGs the peaks are broadened due to the increase in the influence of the terminal hydroxyl groups.

When the peak height is used as a measure of absorbance and graphed against concentration a straight line will be obtained for a particular absorption peak and a range of concentrations of a particular molecular weight grade of PEG. If the line does not pass through the origin this simply indicates that the lower limit of the range scanned was not an ideal point for the initial zero absorbance adjustment but this will not matter provided the same point is always used. Different lines, i.e. with different slopes (and possibly different intercepts) will be obtained for the same peak with different molecular weight grades of PEG (there is an increase in slope with an increase in PEG molecular weight) and for different peaks with the same grade of PEG. Although it would be theoretically possible to use the standard curves obtained by plotting peak height against concentration to determine both molecular weight (by using a series of dilutions to obtain the slope of the relevant line) and concentration of PEG in a sample this would (presumably) require the sample to contain only a narrow range of molecular weights of PEG which may not be the case in either treatment solutions or treated artifacts. However, other techniques such as chromatography, thermogravimetric analysis and computer analysis of IR spectra may allow this problem to be solved and these methods are currently being investigated.

When the peak area (obtained in this analysis by cutting out and weighing the actual peaks) is used as a measure of absorbance and graphed against concentration for a particular absorption peak a straight line is obtained which passes through the origin and is valid for all molecular weight grades of PEG.

Thus it is possible to analyse a sample for total PEG content regardless of molecular weight by running an IR spectrum under the conditions outlined above and reading the concentration by interpolation from the standard curve which is obtained by plotting peak area against concentration.

However, the question then arises as to the necessity of obtaining and analysing these infrared spectra when a simple gravimetric analysis (discovered in the course of earlier attempts to repeat Dr. Pang's work) appears to work just as well and takes much less time. The relative merits of these two analytical methods will be investigated at the W.A. Museum in the near future.

It should also be taken into consideration that the sources of error inherent in the present methods of sampling wooden artifacts by coring (contamination of inner sections, possible compression of degraded wood, and even the selection of a representative site for sampling) may be of such magnitude that the use of techniques which are accurate to within a few percent (i.e. both gravimetric and IR methods, of which the latter has a greater associated error) is unnecessary. Given the inhomogeneous nature of wood itself it should be sufficient in practice to be able to determine PEG concentration levels with an accuracy of 5 to 10 percent of the actual values. The gravimetric method proposed involves the extraction of PEG from the core samples with benzene and assumes that all the PEG and only the PEG is extracted. Analysis of the sample weights before and after the extraction will yield results which more than meet the above criteria.

Acknowledgements

We gratefully acknowledge the assistance of the School of Mathematical and Physical Sciences, Murdoch University, for the use of their infrared spectrophotometer and Doug Clarke and Don Ammon for their helpful discussions.

PART II CONSERVATION OF WATERLOGGED LEATHER AND ROPE

This paper covers the treatment of waterlogged leather from three different marine environments and the retreatment of lanoline impregnated leather. Aqueous solutions of polyethylene glycol 1500, Luviskol K-30 (which is a polypyrrolidone also known as Nylon - 4), and glycerol were used followed by freeze-drying in most cases.

Shrinkage and weight loss data are tabulated and a method of treatment is proposed for all types of waterlogged leather.

Some comments are also made on the successful treatment of waterlogged rope and matting.

Treatment of Leather from the *Sydney Cove*

The *Sydney Cove*, a merchant vessel owned by Campbell, Clark and Company of Calcutta, was carrying a speculative cargo of spirits and general merchandise (including some leather footwear) intended for Port Jackson, when she ran aground in 1797 near Preservation Island, Bass Strait, after a stormy passage from Bengal. Some salvage work was carried out several months later. (Henderson, 1980)

Leather treatments mentioned here were carried out on leather recovered from the wreck after its rediscovery in early 1977 and stored in a waterlogged state with the addition of Panacide and/or Thymol. Some of the pieces were obviously shoe soles but most could not be readily identified. The leather was received from Shirley Lester at the Queen Victoria Museum in Launceston, Tasmania.

Impregnation of the leather was carried out using solutions of PEG 1500, Luviskol and glycerol (plus Panacide) (David, 1981) in various concentrations and combinations for between 11 and 14 days followed by freeze-drying. Several of the pieces were treated more than once. Shrinkage of the leather during treatment was calculated by weighing the outlines traced on paper of each piece before and after treatment. The results of the first set of treatments are summarised in Table 1-a below. Where several pieces of leather were treated in the same batch an average shrinkage is given.

The 10% glycerol treatment was by far the best, resulting in leather with good flexibility and colour although some further surface treatment to attain a 'polished' appearance might be considered aesthetically desirable.

Of the other treatments some use might be made of those which resulted in relatively inflexible leather (Table 1-a) for objects which are required to hold a particular shape. Visible wax was removed by careful surface washing with warm water, resulting only in improved appearance.

A second set of treatments was carried out on the control SC13 and on the still-moist SC121 and SC149 pieces. The 'control' leather was painted with 10% PEG 1500/1% Luviskol and the other pieces soaked in a small volume of water. Freeze-drying was then carried out and the results are recorded in Table 1-b.

The final set of treatments were carried out on leather pieces SC13 and SC149 only. These were impregnated in solutions containing 10% glycerol/5% PEG 1500 and 10% glycerol/1% Luviskol (both plus Panacide) respectively, followed by freeze-drying. The results are summarised in Table 1-c.

Table 1.

Identification number	Impregnation solution (% wt/wt)	Shrinkage* (after freeze-drying)	Condition
a) First set			
SC 13	control	20%	poor, too dry
SC 47	5% PEG 1500	11%	fair, relatively inflexible
SC 47	10% PEG 1500	9%	fair, relatively inflexible
SC 47	15% PEG 1500	5%	poor, wax-covered
SC 47	10% PEG 1500/1% Luviskol	none	fair, virtually inflexible
SC 47	10% PEG 1500/2% Luviskol	none	fair, virtually inflexible
SC 29 TB6	10% glycerol	none	good
SC121	15% glycerol	none	poor, too moist
SC149	20% glycerol	none	poor, too moist
b) Second set			
SC 13	painted with 10% PEG 1500/ 1% Luviskol	no change	poor, no change
SC121	soaked in water	11%	poor
SC149	soaked in water	13%	poor
c) Third set			
SC 13	10% glycerol/5% PEG 1500	5% (from initial state) =17% expansion	good
SC149	10% glycerol/1% Luviskol	6% (from initial state) = 7% expansion	fair to good (due to initial condition)

*Shrinkage is calculated with respect to the maximum (waterlogged) dimensions.

Treatment of Leather from the *Vergulde Draeck*

The *Vergulde Draeck* was outward bound for the East Indies from the Netherlands in 1656 when she struck a reef near Ledge Point on the western coast of Australia. The wrecksite was rediscovered in the early 1960s and several expeditions have been undertaken since then resulting in the recovery, among other things, of numerous leather artifacts.

Following the success of the 10% glycerol solution in treating the *Sydney Cove* leather a number of leather items from the *Vergulde Draeck* were treated similarly. This resulted in leather of reasonable appearance and strength but with shrinkages ranging from 4% to 22%. See Table 2-a.

Further experiments were then carried out as summarised in Table 2-b and 2-c. From these results it can be seen that considerable improvement has occurred since the initial treatment. As well as shrinking less on drying out the leather now has improved flexibility; strength and appearance were unaltered and still satisfactory.

A number of leather items from the *Vergulde Draeck* had previously been treated with toluene/lanoline. These were considered unsatisfactory due to the considerable excess of sticky lanoline which readily picked up dust particles during storage.

The lanoline was first removed from these by immersion in toluene and the removal was considered complete when no further dry weight loss was noted for the leather pieces (about four hours).

On placing the pieces in 10% glycerol rehydration immediately began, resulting in an expansion in area of 25% in a few minutes. This corresponds to the reversal of the maximum shrinkage we have noted for waterlogged leather on freeze-drying without any treatment.

Table 3 summarises the results of the experiments carried out on three pieces of this leather.

Table 2

Identification number	Impregnation solution (% wt/wt)	Impregnation time (days)	Shrinkage* (after freeze-drying)	Condition
a) First set				
GT 4088 (1)	10% glycerol	13	8%)	leather appears dry and somewhat inflexible
GT 4088 (2)	10% glycerol	13	12%)	
GT 4127 (thicker leather)	10% glycerol	27	13%)	
b) Second set				
GT 4088 (1)	15% glycerol	14	10%	no improvement
GT 4088 (2)	15% glycerol	14	7%	improved
GT 4127	20% glycerol	14	9%	improved
c) Third set				
GT 4088 (1)	25% glycerol	21	4.2%	satisfactory
GT 4088 (2)	25% glycerol	56	1.2%	satisfactory
GT 4127	30% glycerol	continuing		

*Shrinkage is calculated with respect to the maximum (waterlogged) dimensions.

Table 3

Identification number	Impregnation solution (% wt/wt)	Impregnation time (days)	Changes in area* (after freeze-drying) cf. Waterlogged dimensions	cf. Lanoline treated dimensions	Condition
a) First set					
GT 4074 (1)	10% glycerol	14	-18%	+ 3.4%	) unsatisfactory, too
GT 4074 (2)	10% glycerol	14	-20%	+ 0	) dry and brittle
GT 4074 (3)	10% glycerol	14	-20%	+ 0	)
b) Second set					
GT 4074 (1)	15% glycerol	56	-14%	+ 8%	) improved but still
GT 4074 (2)	20% glycerol	21	-15%	+ 6%	) not completely
GT 4074 (3)	20% glycerol	56	-11%	+12%	) satisfactory

*Calculations of the percentage shrinkage or expansion after freeze-drying are based on the maximum i.e. waterlogged dimensions and on the minimum i.e. lanoline treated dimensions.

Treatment of Leather from the Long Jetty

The Long Jetty is the remains of a wooden jetty off the coast at Fremantle which was in use between 1872 and 1921. Thus the leather recovered from this site can be assumed to be between 60 and 110 years old. The leather pieces used here were sections of two shoe soles of between 3 and 6mm thickness, recovered from about a metre below the sand in several metres of water.

These experiments were originally designed to consider the effect on leather of different lengths of time in aqueous solutions of 25% and 30% glycerol. Due to the shortage of leather items at the time the experiments were started, however, it was decided to conduct the experiment by re-using each piece of leather. This was done by replacing each piece in the appropriate solution after it had been dried, weighed and measured the previous time.

The results are summarised in Figures 3 and 4.

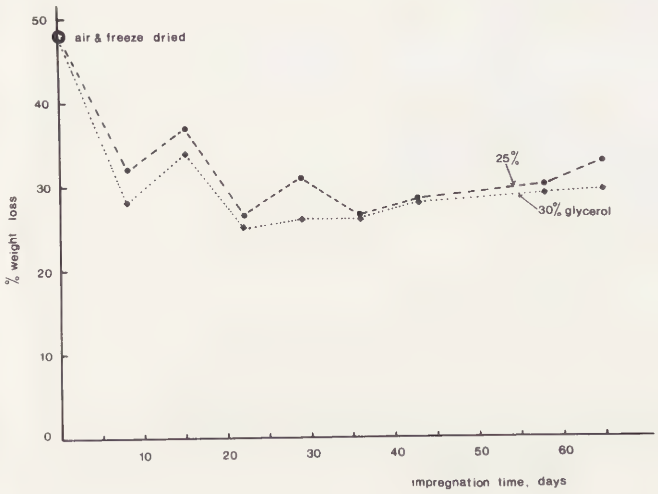

Figure 3. Percentage weight loss of leather versus impregnation time (i.e. the total time in aqueous glycerol).
Weight loss calculated after freeze-drying.

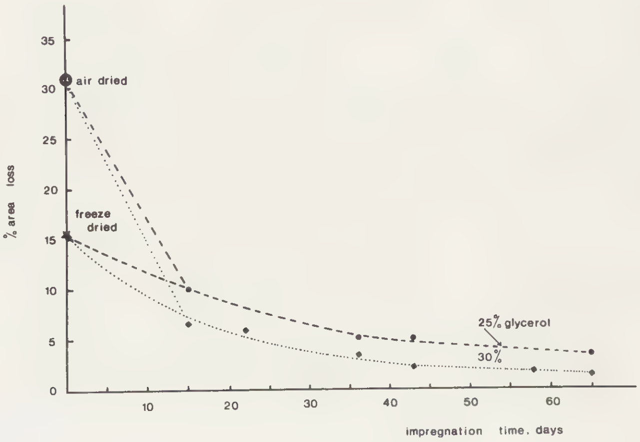

Figure 4. Percentage area loss of leather versus impregnation time (i.e. the total time in aqueous glycerol).
Area loss calculated after freeze-drying.

The values for weight loss and shrinkage at zero days time were obtained from one air-dried piece and one freeze-dried piece. Although the same weight loss was experienced, the shrinkage was considerably less from freeze-drying rather than air-drying. All other pieces were freeze-dried.

In Figure 3 the variation in weight loss may be accounted for in part by the differences in temperature and relative humidity at the different weighing times. The general trend appears to be that the weight loss levels out at between 25% and 30%.

The curves drawn in Figure 4 link the shrinkage values for leather pieces from the thicker of the two shoe soles. Although both curves approach zero shrinkage the 30% glycerol treatment obviously yields better results in a shorter time.

Conclusion

The treatment of waterlogged leather by impregnation in aqueous glycerol solutions followed by freeze-drying yields leather of good appearance, colour, flexibility and strength. While the weight loss on drying will generally be of the order of 25 to 30%, the shrinkage with respect to the waterlogged dimensions can be made negligible.

On the basis of the results tabulated above it is

proposed that all the waterlogged leather in the W.A. Maritime Museum could be treated by impregnation in 30% glycerol followed by freeze-drying. Previously treated unsatisfactory leather could also be successfully retreated in aqueous glycerol using a similar method to that outlined above for GT 4074. See Table 3.

The leather would first be sorted into groups depending on size, thickness and extent of contamination with salts and metal corrosion products. Cleaning of waterlogged leather items will not be discussed at length here although it does appear at present that the safest approach is to clean these by hand every few weeks until a satisfactory condition is reached.

At various times after the start of the glycerol impregnation treatment pieces from each group would be freeze-dried then weighed and measured in order to determine the optimum length of time for each group. These sample pieces could then be replaced in the treatment solution with no adverse effects. If a sample piece was found to contain excess glycerol (shown by a moist surface) then the leather pieces from its group would simply be placed first in water for a few days to completely reverse the treatment and then retreated in a lower concentration of glycerol.

Data on the condition and composition (Jenssen, 1983) of the leather before treatment (dimensions, especially thickness; surface and extraction pH's; results of analyses for protein, moisture, fat, ash, non-hydrolysable matter, tannins, minerals and other contaminants; and animal species if this can be determined etc.) and on the environment of the wrecksite (date of shipwreck, water temperature, whether aerobic or anaerobic, current strength, general chemistry and biology of site, metals in close proximity etc.) could then be considered in conjunction with the impregnation times found to be required for successful treatment. This would indicate which are the most important factors affecting the treatment and would then allow the determination of approximate impregnation times before treatment and the elimination of most of the sample freeze-drying trials.

For example, the better state of preservation of the *Sydney Cove* leather with respect to the *Vergulde Draeck* leather, indicated by the lower glycerol concentration and shorter impregnation time required, could be due to a shorter immersion time (180 rather than 320 years) and a lower water temperature on the wrecksite. The average water temperature at the *Sydney Cove* site is 15.2±1.7°C while the *Vergulde Draeck* site is 21.3±1.7°C. (Ministry of Defence, USSR, 1974) Presumably the characteristics of the leather should also be considered.

Although the glycerol treatment can yield excellent results the following should be taken into account.

Glycerol provides an excellent substrate for microbial growth. This can be prevented by the use of a biocide either in the impregnation solution or during storage and the regulation of temperature and relative humidity during storage.

Glycerol enhances the corrosion of iron. If the artifact to be conserved contains both iron and leather, glycerol should preferably not be used. The substitution of low molecular weight polyethylene glycols is under active investigation at our laboratories.

In some cases glycerol has been observed to gradually settle out in the treatment solutions. This can be avoided by occasional but thorough stirring and should not be significant in view of the relatively short periods (at most a few months) required for impregnation.

Treatment of Waterlogged Rope

Waterlogged rope and matting have been treated very successfully at the W.A. Maritime Museum by impregnation in an aqueous 5% glycerol/5% Luviskol (plus a biocide) solution for periods of time ranging from one to three weeks followed by either freeze-drying or slow dehumidification at 10°C. This treatment yields rope of good flexibility and strength, and very natural appearance. Shrinkage is minimal but the rope pieces should be quite closely bound with fine nylon netting to avoid distortion due to unravelling.

Where there is considerable iron present in the rope, 20% PEG 1500 can be used with similar results.

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Appendix I

For Figure 1

PEG	peak (cm^{-1})	ρ	slope ($mm.ml.mgPEG^{-1}$)	intercept (mm)
1500	1105	0.99997	8.37	13.89
400	1105	0.99975	7.34	11.22
1500	2870	0.99896	5.41	2.08
400	2870	0.99995	4.97	-0.09

For Figure 2

PEG	peak (cm^{-1})	ρ	slope ($mm^2.ml.mgPEG^{-1}$)	intercept (mm^2)
all grades	1105	0.99551	$0.729x10^{-6}$	$1.90x10^{-6}$
all grades	2870	0.99267	$0.342x10^{-6}$	$0.16x10^{-6}$

Section 8

Reference Materials

Matériaux de référence

SARCAR: A NEW ARCHAEOMETRIC RESOURCE

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SUMMARY

SARCAR, the Smithsonian Archaeometric Research Collections and Records facility, has been recently established within the Smithsonian Institution's Conservation Analytical Laboratory. Its objectives include the referencing, preservation, management, and active research utilization of archaeometric data and associated reference materials derived from the scientific analysis of archaeological and art historical objects.

The development of more sophisticated analytical instrumentation combined with increased museum science and archaeological and art historical demand for scientific data relevant investigations of object composition, structure, ancient technological development, production or exchange has lead to the generation of a staggering amount of analytical data. The kinds and extent of the data are as varied as the reasons for its generation. In a museum, questions frequently pertain to conservation or attempts to understand an object's manufacturing history. For archaeology or art history, questions relate to object's composition, source, or date and interest runs from the general "was it made locally or imported" frame to more focused investigations of changes in ancient technology.

While many laboratories in museums, universities, and elsewhere have been involved with such archaeometric investigations for some time, the analyst or the archaeological and art historical collaborators have been more transient. The likely situation is that descriptive data--that's necessary to weave an interpretive narrative--have been only minimally recorded for the laboratory's files and that information necessary for extrapolation beyond a single project is to be found elsewhere. Another situation can be exemplified by the materials left by the great archaeological petrologist Anna O. Shepard. During the years following her death, the thin sections she had studied remained in one institution while the majority of her sherd material was stored elsewhere--some of it reduced to meaningless dust as a result of several moves.

Recognizing the need to establish a depository with curation of the archaeometric reference materials and hard-won analytical measurements, SARCAR, the Smithsonian Archaeometric Research Collections and Records facility has been recently established within the Department of Archaeometry at the Smithsonian Institution's Conservation Analytical Laboratory.

In collaboration with other divisions of the Smithsonian Institution, curatorial facilities will provide referenced storage for samples as well as for archival materials such as spectra, notebooks and bibliographic items. The actual studied specimens, from past investigations, or those promised in the future from current projects, are an important concern. With the contributions of the analytical sciences to archaeology, art history and conservation activities well recognized, no longer is the analyst presented with a "representative" fragment for study. For example: ceramic fragments, pot sherds, are now selected for analysis on the basis of their inclusion of a maximum of cultural information as to location, time, form, style, etc. The analyzed materials are thus not strictly analytical reference specimens. Rather, they are enchanced cultural reference materials. They may be studied in the future and their originally ascribed temporal or stylistic classification altered as more information accumulates. The study materials also may be reanalyzed at some future time in order to evaluate the relative comparability or finding by a different analytical technique. Regardless of specific application, the centralization of reference materials will allow new investigations to grow more efficiently on previous ones.

SARCAR's objectives include (1) providing a centralized facility with continued institutional support for the bringing together and preservation of archaeometric data; (2) space and personnel for the accession, reference and curation of the analyzed archaeometric reference materials; (3) and the implementation of computerized data banking facilities to provide data and object management. The latter will permit on-line retrieval and statistical processing of the analytical data for the purposes of a cooperative registry and research. Of concern as well is an evolving commitment to the reference of data or objects not physically held by SARCAR but which could serve to provide information as to where other similar collections exist.

Misplaced analytical data, incorrect duplication, and forgotten attribution haunt all massive data accumulations. Data management within SARCAR will see to such inventory needs as well as being able to provide a means whereby a researcher may be informed of what other materials relating to his own have been studied. This will avoid unnecessary duplication of effort and will promote the extension of common research interests.

While the preservation of the analytical data and associated descriptive information or objects is a major task, SARCAR is not to be merely dead storage. Rather, a major focus is to provide an active research depository. In order to promote such research activity, analytical data, sorted and retrievable according to the sample attributes encoded within the system, are linked to various pattern recognition multivariate statistical analysis programs.

To a great extent, implementing SARCAR's research objectives depends upon the "kinds" of descriptive information that may be associated with an object's analytical data.

While usual archaeometric interest is generally focused on an object's general style and location where it was found, attributes pertaining to shape, decorative technique, etc. are extremely important. The encoding of these descriptive attributes as well as taxonomic nomenclature will contribute to the utilization of the analytical data by someone beyond the original scholar. It is obvious that there are many levels of object description. Object attributes that may appear to be adequate when one is engaged in an archaeological investigation of long distance artifact exchange may be seen to be inadequate when focusing on exchange within a small region. The encoding of descriptive data is always tricky, not only in terms of attribute terminology but also in its level of inclusiveness. The schema that is utilized is essentially a multi-part design, containing data relative to object or data inventory, formal or descriptive parameters as well as the analytical determinations.

Most of the descriptive data pertains to archaeological or art historical materials and thus a hierarchy of coded parameters have been implemented to enhance the archaeological and art historical research utilization of the data bank. For example, while at the general level, a form class designation may be a generalized term, equally innocuous to archaeologists working in the Old or New Worlds, higher, more specific designations are encoded following the classificatory terminology of the areal specialists. A general designation might serve for broad source attribution of an object; however, investigations of technological history or craft specialization will require more demanding specificity. This level of coding is even more important for the potential utilization of the data by museum curators, for the frequent lack of information as to where an object was made typically forces comparison on a descriptive level

At the present time, analytical data from Brookhaven National Laboratory and its accompanying descriptive information are being added to that generated by the Department of Archaeometry at the Smithsonian Institution. Over 20,000 analyses are included, dealing with pottery, obsidian, jade, turquoise, native copper, bronze and glass. Arealy, the analyses are now numerically biased toward the Near East, Mesoamerica and Costa Rica, reflecting the previous interests of the Department of Archaeometry' personnel. Other areas of concentration are developing through the work of Post-doctoral Fellows in the Department of Archaeometry. Weighted heavily toward data derived by neutron activation analysis, other kinds of data being entered into the data bank include emission spectrographic, atomic absorption, stable isotopes, x-ray diffraction and petrographic examination.

As many data sets relate to objects of a common area or research interests, it is of great importance to insure that the data conforms as closely as possible to a common reference base. Accordingly, the activation data are presently normalized relative to the National Bureau of Standards Standard Reference Material 1633 (Coal Fly) Ash utilized at the Smithsonian Institution. For the widely used Perlman-Asaro standard pottery and the Brookhaven National laboratory's Ohio Red Clay, conversion factors for several elements have been determined.[1] The Ohio Red Clay was originally standardized against six U.S. Geological Survey Reference rock samples (G-2, GSP-1, AGV-1, PCC-1, DTS-1, and BCR-1) and a series of conversion factors to compensate for use of any one of these standards was determined. Entering the data relative to the Coal Fly Ash reference material is facilitated as consequence of the conversion factors determined for Ohio Red Clay. As the situation arises, additional conversion factors must be determined for standards other than those mentioned above.

While archaeometrists or archaeologists are primary consumers of archaeometric data, museum curators and conservators also benefit and are important contributors to the SARCAR data bank. As an example, an extensive, multi-year investigation of pre-Columbian Maya polychrome pottery was undertaken by the Museum of Fine Arts in Boston and Brookhaven National Laboratory. Over 12,000 samples of excavated and surface collected pottery, manufactured during 600-800 A.D. were analyzed by neutron activation analysis. Among the project's objectives was the attribution of the non-provenienced Maya pottey held in museum collections to highly restricted, chemically-defined sites or sub-regions. Over 20 museums, including those in Latin America, the United States, Canada, England and Germany allowed vessels in their collections to be sampled. Painting styles, themes, individuals and glyphic texts shown on the vessels may now be attributed to restricted areas leading to new sub-regional considerations of Maya ceramic art. For the museums, their vessels are now related to a larger body of archaeological material and to vessels in other museums. In other words, the informational value of the object has been enhanced. Such utilization of an archaeometric data bank could be applied to other areas and cultures as well.

Institutional commitment, archaeological and art historical orientation, and an emphasis on the research utilization of an archaeometric data bank as well as the preservation of the analyzed reference materials, characterize SARCAR's beginning. For SARCAR to carryout its objectives, national and international cooperation must be obtained. We do not presuppose to be the <u>only</u> centralized data bank but rather we seek to provide <u>a</u> facility to guard against the loss of information painstakingly obtained by archaeometric activity. Earlier recognition of similar needs for museum laboratories lead to the creation of the Working Group on Reference Materials by the International Committee on Museums.[2] Ours is one response to that recognized need and we welcome comments and suggestions from the international museum community.

(1) M.J. Blackman, J.S. Olin and A. Jornet, "The Use of Interlaboratory Data Sets in Provenience Studies," Paper presented at the 24th International Archaeometry Symposium, Washington, D.C. May 14-18, 1984.

(2) R.J. Gettens, Preliminary Report on Reference Materials, ICOM Committee for Conservation, Amsterdam Meeting, September 15-19, 1969.

IDENTIFICATION OF THE FORBES COLLECTION PIGMENTS

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SUMMARY

A large group of pigments (approximately 6200 examples) was assembled by the late Edward Waldo Forbes, former director of the Fogg Art Museum. This collection contains well known organic and inorganic pigments as well as a large number of rare and unusual Oriental specimens. From this large body of material, selected samples were distributed to various museums and other institutions throughout the world. These pigments are commonly used both as a study collection and as conservation material. Following an informal study of the samples, we found that many were incorrectly identified or lacked identification. This led to a detailed study of the composition of the pigments and determination of their proper identification.

INTRODUCTION

Edward Waldo Forbes, former director of the Fogg Art Museum at Harvard University, Cambridge, Massachusetts, added continually to his collection of pigments during a lifetime of extensive travel. The collection of approximately 6200 samples contains organic and inorganic materials, both in natural and manufactured form. Of special interest are dry pigments purchased in Japan, some of which are rare and unusual to European and American artists.

During his lifetime, Forbes gave sets of reference material to the Fogg Museum, the Yale University Art Museum, Intermuseum Conservation Laboratory, Oberlin, the Freer Gallery of Art, Washington, D.C. and the Museum of Fine Arts, Boston. This material is considered to have formed the "core" or original Fogg Museum collection. After his death (Mr. Forbes died in 1969), a portion of the Forbes collection was donated to the Institute of Fine Arts, New York University, with the understanding that further sampling could be taken from it in order to provide material to other institutions.

It has always been assumed that the New York University collection was essentially a duplicate of the Fogg collection. However, it appears that there are a number of materials in the former that are not in the Fogg collection and vice-versa. To date, a comparative list of both collections has never been published.

As presently understood, the disposal of samples from the collections is as follows:

Fogg Museum (core) Collection

Fogg Art Museum (Cambridge, Massachusetts)
Intermuseum Conservation Laboratory (Oberlin,Ohio)
Balboa Art Conservation Center (San Diego,California)
New York University Conservation Center of the Institute of Fine Arts (New York, New York) *
Art Institute of Chicago (Chicago, Illinois)
Philadelphia Museum of Art (Philadelphia, Pennsylvania)
Yale University Art Gallery (New Haven, Connecticut)
Museum of Fine Arts (Boston, Massachusetts)
Freer Gallery of Art (Washington, D.C.)

New York University (Forbes' Private) Collection

Metropolitan Museum of Art (New York, New York)
Winterthur Museum (Winterthur, Delaware)
Walters Art Gallery (Baltimore, Maryland)
Detroit Institute of Arts (Detroit, Michigan) *
Intermuseum Conservation Laboratory (Oberlin, Ohio)
Carnegie-Mellon Institute (Pittsburgh, Pennsylvania)
Library of Congress Restoration Office, (Washington, D.C.) *
National Gallery of Canada (Ottawa, Ontario, Canada)
Conservation Center of the Institute of Fine Arts, New York University (New York, New York) *
McCrone Research Laboratory (Chicago, Illinois)
Cooperstown Graduate Programs--Conservation of Historic and Artistic Works (Cooperstown, New York)
Doerner Institute (Munich, West Germany)
Univeristy of Stellenbosch (Stellenbosch, S. Africa)
National Research Laboratory for Conservation, (New Delhi, India)

(Note: asterisk (*) designates samples which have been mounted on slides for study/reference purposes)

Informal studies of the samples held in several institutions have resulted in suggestions that some materials were incorrectly identified. In addition, several samples have no identification and the oriental samples are normally identified in general terms with japanese words or phrases, i.e. suisho (ground up crystal).

To allow this important collection to be used in the best possible manner, we have decided to pursue a detailed systematic study of the composition of the pigments. By doing so we hope to determine their proper identification and periodically publish these results.

Analytical results from the following pigment groups will be presented at this conference: whites, yellows, oranges, browns, blues, violets and greens.

EXPERIMENTAL METHODS

The collection contains a wide variety of materials, organic and inorganic in both natural and commercially manufactured forms. Because of this great diversity, we have had to use a number of analytical tools. These include: x-ray diffraction, energy dispersive x-ray fluorescence, thin layer chromatography, infra-red spectrophotometry and emission spectroscopy.

Many pigments in the collection are represented by very small amounts of material. We have concentrated on small sample techniques.

RESULTS

An illustrative example of the results can be given through a partial discussion of the white pigments.

From a total of 86 possible pigment samples in the collection, we have analyzed 84. (Two samples were unavailable, even after requests to other institutions. In fact, many of the remaining pigment samples, throughout the collection, are very small, of the order of tens of micrograms.) The white pigment group contained five examples having no previous identification and eight oriental pigments with limited information. These were fully identified. In checking the correctness of previous identification, we either confirmed this information, or,for twenty additional pigments, the identification was corrected or clarified.

In addition to the white group, the other groups studied are:

Yellow--There are 204 possible samples, we have 142 available; we have identified 29 and continue research on the remainder.

Brown--There are 52 possible samples, we have 51 available; we have identified 25 and continue research on the remainder.

Orange--There are 27 possible samples, we have 27 available; all have been identified.

Blue--There are 111 possible samples, we have 103 available; we have identified 95 and continue research on the remainder.

Violet--There are 19 possible samples, we have 9 available; we have studied 5 and continue research on the remainder.

Green--There are 117 possible samples, we have 87 available; all have been studied.

The analytical results will be published as they are completed; the first group, the white pigments, has been recently published (Carriveau and Omecinsky, 1983). For future publication, we intend to develop a standardized format to simplify the display of all information. Working towards that goal, we have developed a unified data sheet so that all of the available information can be contained in a computer data base management system.

A discussion of the experimental methods, the results and computer data base will be presented.

ACKNOWLEDGEMENTS

We wish to thank the Department of Chemistry, Wayne State University, Detroit, Michigan, where some of this research was done.

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Section 9

Textiles

Textiles

TEXTILES

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Programme 1981 - 1984

1. To promote responsible conservation of textile objects of artistic and cultural importance through communication among the members.

2. To encourage the exchange of experimental findings or other relevant information providing this does not interfere with the sovereignity of a particular work or with the priority reserved for the publishing of this finding.

3. Promotion of contacts between various groups concerning the conservation and study of historical and cultural textile objects outside ICOM.

4. To examine the merits of available methods and to develop new ones in matters concerning cleaning and reinforcement of fragile textiles.

5. To study the possibilities of protection of textiles against influence of exposition, storage and air pollution.

6. To study the composition of textiles and dyestuffs in their historical context.

7. To assess existing training programms and to stimulate their developement by propagating themas as well as by translating the instructions on which they are based into various languages.

Introduction

In textile conservation various groups are concerned with study and research in the field. Historical and art historical problems are studied in the CIETA (and held their conferences in Florence and Lyon. In the ATM (Germany) an active group of textileconservators held their meeting in Hamburg last year. In Veszprém the Hungarian Institute of Conservation held last year a symposium with main topics the conservation of two sided painted flags and embroideries. The dutch Textile Committee prepared publication with basic principles of conservation which will be published in more languages. In Washington the Harpers Ferry symposium on relining of textiles was held. Members of the working group visited these conferences so that information was exchanged.

Various studies are carried out in the field of influence of humidity on aging of cellulose, and the buffering of cellulose. Fireretardents and moth proofing agents has been tested and their influence on ancient textiles.

Also modern materials has been studied. Early synthetic fibres become more frequent in textile collections in museums, a study of there production is made.

Cleaning agents and spot removal has been studied and their consequences for the ancient textiles.

Various conservation treatments of textiles of important cultural value are made, where the cooperation of conservators and scientists is significant.

In the field of the conservation of flags and banners much work is already done. There is a strong feeling however, that more cooperation should be found between paint conservators and textile conservation to solve the problems in this field together.

The promotion of exchange of experience in the field of conservation of textiles is strongly feld by the coordinator and the possibilities of this exchange will be discussed in the working group.

MOTHPROOFING MUSEUM TEXTILES

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SUMMARY

This paper will review the major industrial textile auxiliaries that have provided residual protection against insect damage for wool fabrics. A brief survey of current museum practices in the United States will follow. The aqueous application method of a suitable agent, Eulan U33, will be described for use in protecting museum wool textiles which can be wet cleaned.

The standard specifications for textile exhibition conditions refer to the ambient light, temperature, and humidity levels. There are no standard specifications to protect the large, cumbersome, delicate wool textiles like tapestries or carpets from the insect environment of the city, town, or country where the object is on view. Although the art objects arriving at a museum are generally inspected and sometimes fumigated, the museum staff, the visitors, and the viewing public arriving at a museum are not. Coats, sweaters, and jackets are not monitored for cleanliness or for proximity to the wool museum objects; florists and floral arrangements are rarely checked (34). While restricted access and good maintenance can protect objects in storage, the objects on view are entirely vulnerable to insects whose appetites have been characterized as 'voracious' (26).

To redress and to reduce such vulnerability, this paper will first review the major industrial textile auxiliaries that have historically provided residual protection, then present a survey of current American remedies, and finally, describe the wetside application and agent found most suitable for museum textiles like tapestries and carpets.

1. Industrial Mothproofing Agents

Fumigation eradicates an insect infestation by lethal gas but it leaves no residual protection for the wool object. Depending upon the fumigant and its dosage, the death of the dormant eggs may or may not be achieved (34). Similarly, insecticides destroy the insect population *in situ* by acute toxicity, rendering the immediate environment deadly to larvae and to adult insects. In both instances, the actual textile objects remain vulnerable; only their immediate environment is affected (31). By contrast, mothproofing (insectproofing) agents are applied to the wool fiber (as loose wool, yarns, or piece good) to impart a lethal residue within the fiber. The chemical compound is fixed in the wool like a dye; the wool molecule itself is not modified. The fiber is rendered toxic to the insect which attacks it, and thus the object is protected through time regardless of its environment.

Among the earliest effective mothproofing agents was Manchester Yellow or Martius Yellow, 2,4,-dinitro-α-naphthol (C.I. Acid Yellow 24, C.I.#10,315). It was an early synthetic dyestuff often used in wools dyed green. Only 0.25% o.w.f. (on weight of fabric) was found to impart mothproofing protection to wool fabric. This investigation of mothproofing with dyestuffs, begun by E. Merkbach of the German Dye Trust in 1917, proved to have limited success: undyed portions of the fabric would still be susceptible to damage; other dyes of different hues did not have the protective property that Manchester Yellow imparted to the textile (1,26).

New avenues of organic research searching for a suitable mothproofing agent branched in several directions: colorless dyes, primarily the triphenylmethanes; acid fluorides or salts like chromium fluoride; and pentachlorophenol. Extensive patent literature may be found, beginning in 1919, on acid fluorides and salts (5, 26). While most of the fluorides were not substantive to the wool, they could be used in wet finishing where their acid form would be 'fixed' to the wool. As little as 0.2% o.w.f. fluorine produced effective mothproofing (33). However, these results, at best, were not adequately washfast, and could cause a harsh handle to the fabric or a greenish tint (26,33). Pentachlorophenol, a small aromatic halogenated molecule, has a similar liability. Although it can be applied in wet finishing, at relatively low temperature (40^{o}-50^{o} C.), the requisite 0.3-1.2% o.w.f. will not remain fast to washing (7,26,33).

Efforts to produce a colorless and odorless mothproofing agent that was fast to washing and to light were rewarded in 1928 when I.G. Farben (now Bayer) patented Eulan New. Like pentachlorophenol, this triphenylmethane is halogenated. It is rendered substantive to wool in aqueous solution with the aid of a sulfonic acid group. The relatively high quantity required to impart mothproofing, 3.0% o.w.f., was offset by its lack of interference with simultaneous dyeing (7,26). It was not fast, however, to fulling operations and in 1934 Eulan CN Extra, with an additional chlorine, appeared on the market (26).

Further experimentation followed. An attempt to substitute the central carbon atom of the triphenylmethane series with a phosphorus atom led to Eulan NK. This product could be exhausted from a neutral bath at 40^{o}-50^{o} C. and could be used with neutral soaps. However, it was inappropriate for use with acid dyes and could be leached from the fiber during subsequent washings (7,26).

Another I.G.Farben product, also introduced about this time, was Eulan BL. Here a sulfonamide group was added to a chlorinated benzene ring; the fundamental loxicity of an 'organochloride; compound was thus joined to an antimetabolite or stomach poison (33). Despite its insolubility in water, Eulan BL could be used as an aftertreatment during drycleaning. It was lightfast but was found to complex with direct dyes containing sulfonic acid groups and to render these dyes fugitive to light (7,26).

In 1938, J.R.Geigy (now Ciba-Geigy) introduced a dichlorodiphenyl ether on a substituted urea group, with the brand name Mitin FF. A sulfonic acid group induces water solubility and satisfactory affinity to the wool fiber (32, 2). Compatible with acid dyestuffs, Mitin FF is substantive to wool fiber; it renders wool mothproof with 1.0% o.w.f. when applied at temperatures above 60^{o} C. (20,26). Because

of historic events, Mitin FF became widely used until the advent of D.D.T. and, subsequently, of Dieldrin (33).

Dichlorodiphenyl trichloroethane or D.D.T. provided short-term mothproofing with as little as 0.1% o.w.f. (26,33). Nevertheless, as early as 1944, it was found to be 'slowly volatile' and lacking any affinity for wool (26). These factors, together with its non-aqueous means of application, reduced the merits of D.D.T. as a permanent mothproofing agent, although the necessity of substantivity to the wool fiber was questioned (5). If the purpose of the mothproofing agent was to protect the wool in storage or during processing (i.e. the rovings, yarns, pieces, etc.) prior to sale and distribution, then the absolute permanency of the mothproofing agent to washfastness, lightfastness, et al. would have been superfluous (7).

Dieldrin, patented by Shell in 1954, was similarly insoluble in water but was an excellent toxic agent at very low concentrations, effective to 0.005% o.w.f. (23). Applied from an aqueous emulsion to achieve 0.05% o.w.f., Dieldrin was widely esteemed as an inexpensive mothproofing agent (2,23), Like D.D.T., its low wash fastness was not inimicable to its use because of its high toxicity, Recently, its carcinogenic properties have been defined and Dieldrin has been removed from the market. Even its product literature is no longer available from the manufacturer.

The current industrial competitor of Mitin FF is Eulan U33 (marketed as Edolan U in the United States). Like Mitin FF, Eulan U 33 is a chlorinated diphenyl ether but the substituted urea group is replaced with a sulfonamide group. Eulan U 33 is miscible in water, and is substantive to the wool fiber down to 40° C. (2, 20). The affinity of Eulan U 33 to wool may be causedby the ionic bond of the chlorinated sulfonamide, although the main agent for the bonding is thought to be the interaction of molecular forces: hydrogen bonds, dipolar forces, dispersion forces (2, 27).

Today, research on mothproofing agents involves the development of after-treatment agents based on the conversion of temporary insecticidal or fungicidal compounds to those with mothproofing permanency (3,4,8,10,28). Other types of chemical reactions continue to be explored (11). It is thought that the restrictions on chlorinated hydrocarbons and the high costs incurred to substantiate and to evaluate potential products will require this corelation of wool and agricultural research in the future (3,4). Principal among the new studies are Permithrin and Resmethrin, two synthetic pyrethroids (3,4,10,21),

In addition, there is concern that insecticides and mothproofing agents will disturb the lightfastness of fibers blended with nylon or polyester (10). It is already clear that blends of nylon and wool will reduce the uptake of mothproofing agents on wool (20). Thus, the quantity on weight of fiber can be inadvertently reduced, leaving the wool without adequate protection. Consequently, there is the hazard that improper application levels could eventually allow a mothproof-resistant strain of moth or beetle to develop (20).

The desired properties for mothproofing agents now, as in the past, include the following:

a) Compatibility with existing processing methods, like dyeing or cleaning
b) Permanent toxicity to insects which attack and ingest wool
c) Colorless and odorless compounds
d) Fastness to light (photostability)
e) Substantivity to wool fiber--fastness to washing, drycleaning
f) Compatibility with other textile auxiliaries, other dyes, other fibers
g) Ease of actual application
h) Low cost
i) Lack of carcinogenic hazard.

Table 1. Mothproofing Agents

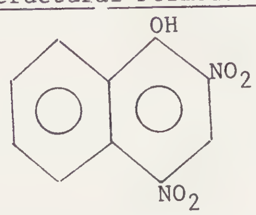
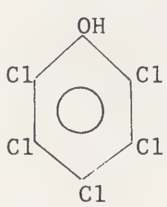
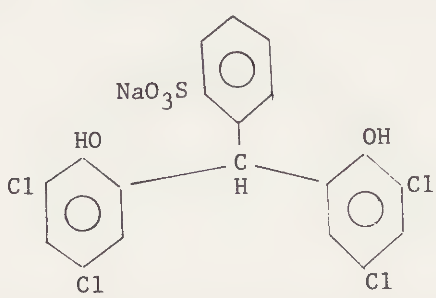
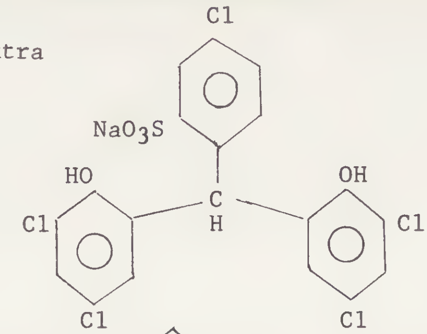
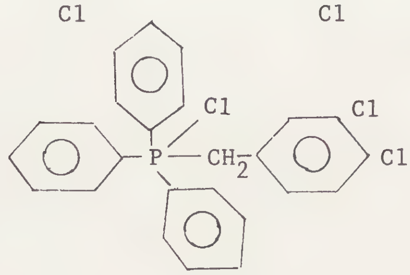
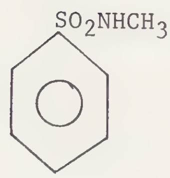
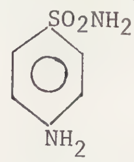
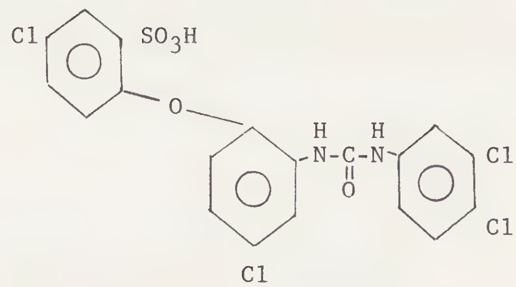
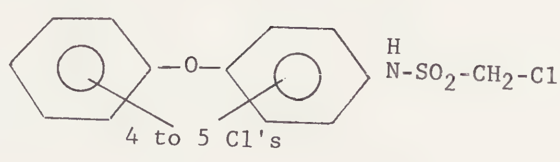
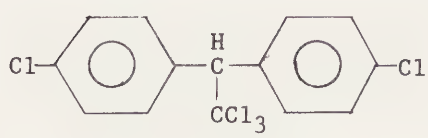
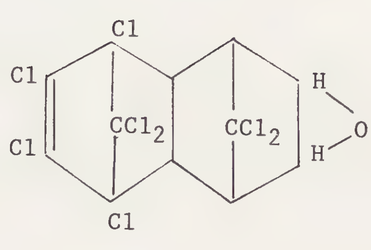
Class, Chemical Type	Brand Name(s)	Structural Formula	Notes	Source
Dinitrophenol	Manchester Yellow Martius Yellow		Color Index Acid Yellow #24, Color Index Number 10,315	(1)
Fluoride	Eulan W	X $(HF)_n$ where X is an organic or inorganic alkali salt or a metallic fluoride		(26)
Pentachlorophenol	Mystox B		Mystox LS is pentachlorophenyl laurate	(26)
Triphenylmethane	Eulan New			(7)

Table 1. Mothproofing Agents, continued

Class, Chemical Type	Brand Name(s)	Structural Formula	Notes	Source
Triphenylmethane, cont'ed	Eulan CN Extra			(7)
Triphenylphosphine	Eulan NK			(7)
Sulfonamide	Eulan BL		similar to the anti-metabolites:  sulfanilamide  p-aminobenzoic acid	(7,22, 23)
Dichlorophenyl ether with substituted urea	Mitin FF			(2,22,23,32)
Chlorophenyl ether with methyl sulfonamide	Eulan U 33 Edolan U Highly Conc.			(2,22,23,27)
Dichlorodiphenyl trichloroethane	D.D.T.			(26)
Hexachlorodimethano-naphthoxirene	Dieldrin Dielmoth		banned in the United States	(2,22,23,25)

2. Survey

Despite the considerable industrial research and development of mothproofing agents by chemical companies, government institutions, and private consortiums during this century, the use of such textile auxiliaries in museum related treatments has been limited. Apart from purchasing mothproofed repair yarns, caretakers of American museum textile collections do not appear to have made any use of mothproofing agents. Indeed, the chief non-industrial users in the United States seem to be a) natural history museums, b) fiber artists working with felt, and c) other hand weavers (6,9,12,13).

Natural history museums, particularly, have found that a non-restricted industrial mothproofing agent, Edolan U (known elsewhere as Eulan U 33) provides a residual protection for their specimens between periods of examination. They apply it in an aqueous solution or with isopropanol (9,12). By contrast, no textile collections in the United States are known to be protected with any mothproofing agents, although several fine arts museums are known to have been subject to beetle or moth infestation in recent years. Concern over the apparent inscrease of infestations have led museum scientists and conservators to develop seminars and literature on fumigation, pesticides, and non-toxic alternatives (29,31,34). Still, fumigation, 'house-keeping,' and insecticides have been preferred. The limitations of these three standard methods may be summarized as follows:

a) Lack of residual protection of the textile
b) *Fait accompli* damage to the object prior to identification of its condition by museum staff
c) Detrimental effects to museum personnel and objects from prolonged exposure to insecticides
d) Increasing prevalence of insect infestation in private homes
e) Cost of fumigation, cost of installation and operation of a fumigation chamber
f) Staff time in continually examining objects
g) Hazard to objects during such handling
h) Difficulty in killing dormant eggs with current methods.

3. Use and Application of Mothproofing Agent on Museum Textiles

Because the vast quantities of specimens in natural history museums are not handled extensively by preparators, conservators, or curators after treatment with Eulan U 33, the fixation of the mothproofing agent can be simply mechanical (a simple spray). A slight change in the feel of the surface of the specimen--which may occur if an isopropanol/Eulan U 33 solution is used--is unimportant. Comparable to this would be the woolen case lining fabrics favored by certain museum curators and designers.

However, with textile collections, the feel or flexibility of the fabric is crucial and the substantivity to the wool fiber is paramount. Since subsequent conservation treatment (tapestry or carpet repair) can involve prolonged exposure and contact between the surface of the textile and museum staff, the permanent chemical fixation of the mothproofing agent is critical. Thus, spray application methods are NOT recommended for museum textiles (6, 16).

Yet, of the industrial mothproofing agents currently available in the United States, Edolan U (Eulan U 33) has several advantages: it can be fixed at low temperature and during other routine treatments (wet cleaning, rinsing); it is easy to apply; there is a great deal of documentation on it from research by the manufacturers and independent agencies over the course of several decades (6,9,12,13, 18,20, 23,27). Furthermore, there are chemists, technical representatives, and independent agencies to answer questions and to analyze application results ('production runs') (6,20). For museum textiles, the procedure used for 'aftertreating' wool fabrics is recommended (6,16,19,20,27).

That is, Eulan U 33 can be applied to museum textiles which can be submerged in warm water during wetcleaning, textiles such as carpets, blankets, or tapestries. As a general practice, the textile is wetcleaned in the bath prior to treatment with the mothproofing agent. In any case, it should be thoroughly wetted and rinsed to remove any residual cationic agents or any soluble products of wool decomposition which would complex (precipitate) the sulfonamide (16,20,27).

With this method, as modified by the author for museum tapestries, the rinsing baths are gradually brought up to a temperature of 40°-45° C.; a diluted solution of Edolan U is then distributed throughout the bath. A bath concentration of 4-5 grams/liter Edolan U/water with a liquor ratio of 250:1 has proved satisfactory. Ideally, the liquor ratio should be between 25:1 and 100:1 (16). The tapestry remains in this bath for 45 minutes with only minor agitation of the bath. Then a 1 gram/liter glacial acetic acid prediluted with water (40°-45° C) is distributed in the bath. This reduction in pH increases the affinity of the wool for Edolan U (6,18,20)After an additional 30 minutes, the bath is drained. A final rinse in 38°-40° C. water is considered prudent to remove unfixed (unexhausted) Edolan U. The tapestry is then allowed to air dry.

This method involves a 6% on weight of wool fiber application of Edolan U (1 pound Edolan U/18 pound tapestry) since the high affinity of the mothproofing agent for the wool is not realized: optimum conditions for exhaustion include a pH 4-5 (6,18,20). If the textile can tolerate the lower pH level, the application level or concentration could be reduced (6,19,20). Under optimum conditions, a 0.8%-1.0% o.w.f. application level has been recommended (6). Industrially, effective protection has been found for carpets, blankets, etc from application levels of 0.4-0.6% o.w.f. (6, 20).

Here it must be emphasized that there is a difference between the amount of Edolan U applied in the bath and the actual amount of mothproofing agent, the chlorinated diphenyl ether with sulfonamide, in the bath (16). The active ingredient is 33% of the total industrial product. Like other mothproofing agents, the 'on weight of fabric' refers to the total application, not the percentage of active ingredient. With Edolan U, only one-third of the application concentration becomes the effective concentration of active mothproofing on the fiber.

Moreover, the real quantity of the active agent in Edolan U taken up by the wool fiber can only be determined by analytical testing. Since the finished textiles or museum objects cannot be directly subjected to such testing, a sacrificial blank of undyed, untreated wool fabric (worsted or semi-worsted for tapes-

tries) should be included in the baths for this purpose. Current results show a 0.38-0.42 % active protection for the objects treated; this translates into an application level of 1.14-1.25% o.w.f..using this method.

It is recommended that the conservator anticipating the use of such an auxiliary in the wet bath, practice upon non-museum items of only personal interest prior to mothproofing an accessioned object. The manufacturer's directions should be thoroughly reviewed and explicitly followed. Heavy duty plastic gloves and protective clothing (aprons) should be worn when mixing the mothproofing agent; the use of goggles and a face mask are suggested. Time should be allowed for draining and filling the bath. Although demineralized water is preferred for the aqueous cleaning of wool fabrics, the mineral content will not affect the performance of Eulan U 33 (27).

In using this 'aftertreatment' method for tapestries and other textiles, the handle of the object remains unchanged. Indeed, there is no change in appearance to be noted in either the published or unpublished lightfastness testing with Eulan U 33 (Edolan U) (6,19,20, 23, 27). Large, cumbersome, or awkward wool textiles can be effectively treated in this manner provided that they are wash-fast and that the wet cleaning facilities are available. Thus, tapestries and carpets subsequently exposed to a less than fastidious viewing public or neatly rolled in storage can be assured of a greater longevity with a greater percentage of the original, extant weaving and workmanship protected for future generations than by any other method of protection.

Edolan U is distributed in the United States by Mobay Chemical Corporation; elsewhere, as Eulan U 33, it is distributed by Bayer.

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TEMPERATURE AND HUMIDITY EFFECTS IN THE ACCELERATED AGING OF CELLULOSIC TEXTILES

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SUMMARY

The author has previously reported on investigations of the efficacy of alkaline treatments in reducing the rate of degradation of cellulosic textiles (1,2,3). These studies were conducted using new, artificially aged and naturally aged fabrics, and degradation was accomplished by baking at 150°C in a dry oven. The results showed that alkalization and buffering, while effective for new cloth, was no more useful than a simple rinse in deionized water in protecting old cloth.

This work has been criticized on the grounds that accelerated aging at 150°C could introduce new chemical mechanisms or so modify existing mechanisms that the results could not be used to predict the effects of treatment and storage at ambient conditions. In this paper, the author discusses the results of an analysis of past literature and the results of recent experiments in his own laboratory. It will be shown that while precise control of temperature and humidity during the course of an experiment is of great importance, the exact experimental conditions are not.

INTRODUCTION

The conservator seeking to apply the proper treatments to extend the lifetime of cellulosic materials must rely upon experiments conducted at elevated temperatures when assessing the utility of different methods. This is so because, as Little (4) points out, the half life of cellulosic fabrics stored under ambient conditions is about 2000 years, and it would take over 5000 years to degrade fabric to 10% of its initial strength. Thus, it is impossible to conduct experiments at room temperature which will give results that can be extrapolated to the lifetime of the fabric. Most of the research aimed at the conservation of cellulosic materials has focused on paper, and not unexpectedly the test procedures developed for accelerated aging of paper have been appropriated for the aging of fabric. Yet, for many years investigators have argued over the proper conditions for conducting accelerated aging tests. There appear to be two schools of thought: (1) those advocating baking at 100°C in a dry oven, and (2) those who prefer baking at 95°C and 50% relative humidity. Proponents of each method have argued that their procedure gives results which are "more like natural aging" than the other.

It must be realized, however, that fabric is not paper; and that while paper may be degraded to 10% of its initial fold endurance within a week at 100°C, it would take over two years (4) to achieve a similar result with cloth. Thus, the questions facing the conservation scientist investigating methods of preserving textile products are: (1) how high a temperature can be used in accelerated aging without affecting the chemistry of the system, and (2) what level of humidity must be employed? Thus, the argument of damp vs dry oven is carried to higher temperatures.

It could be argued that experiments conducted at high humidity enhance those chemical reactions which depend upon water, while experiments conducted in a dry oven suppress them. It has, in fact, been shown (5- 9) that both increasing moisture content and elevating temperature will accelerate reaction rates. It has also been shown that at temperatures above 200°C, chemical reactions, e.g. the production of levoglucosan, take place which do not occur at ambient conditions (10). Thus, an upper limit to the temperature would be no higher than about 180°C.

ANALYSIS OF THE LITERATURE

Very few studies of the effects of temperature and humidity on the accelerated aging of cellulosics have been published. In review articles Neimo (11) in 1964, Luner (12) in 1969 and Roberson (13) in 1976 have stated the need for more information. However, an analysis of the reports cited in Refs. 1 - 10 as well as that of Schwalbe and Robinoff (14) does allow us to determine the appropriate conditions for testing. The criteria for selecting these studies were simply that they provided data on the chemical and/or mechanical properties of cellulosic materials as a function of temperature and humidity. In addition, the results of current work in progress at this laboratory on the measurement of fabric degradation at oven temperatures between 100 and 150°C are included in the analysis.

The following assumptions were made: (1) the results of the measurement of the degradation of the physical or chemical properties were first order and could be modeled by an equation of the form

$$\ln Y = kX + b, \text{ and}$$

(2) the results at different temperatures could be described by the Arrhenius Equation

$$\ln k = \Delta E/R \cdot 1/T + c, \text{ where}$$

Y is the property being measured, k the degradation rate constant, X the aging time, ΔE the activation energy, R the gas constant, T the temperature, and b and c are constants.

If the results fit the above model, a change in the activation energy over the temperature range indicates a change in mechanism. If, however, the activation energy is constant, then it must be accepted that the chemical mechanisms are constant over the temperature range of interest. Furthermore, if the activation energy at different humidities is the same as the activation energy in a dry system, then it must be accepted that humidity changes do not change the mechanisms.

The data from the above listed references, and the data from studies conducted in this labortory, were provided as input for a computer program which used standard statistical methods (15) to determine a least squares regression line of the extent of degradation as a function of aging time for each temperature and relative humidity. The slopes of these lines (the rate constants) were then fitted to an Arrhenius plot for each data set and the activation energy determined by least squares analysis. Finally, the calculated slopes were tested by a standard "t-test" to determine if any differences existed (a) between values for results obtained under dry vs humid conditions and (b) for values within and between data sets.

The treatment of the data is shown in the following figures. A typical aging curve is shown in Fig. 1 in which the ln(Strength Retained) is plotted vs Baking Time. It should be noted that the curvature of the plot indicates that more than one mechanism is operating; so that either the initial straight-line portion of the curve or the later straight-line portion of the curve should be used, but the entire curve should not be forced to fit a straight line. It is possible to fit the entire curve using two or more rate constants, but the effort involved is not warranted as the conclusions remain the same. In general, it is the initial portion of the curve that provides the more useful data, since extraneous second-order effects which may become important after long aging times are not present.

Figure 2 shows an Arrhenius relation typical of one in which data from two authors are plotted. This example is based on the data from Refs. 4 and 5. Note that although the values of the rate constants are not exactly the same, the lines are essentially parallel. The shift between the two lines can be explained by differences in (a) material used, (b) property measured, and (c) investigators. Similar curves are developed when comparing temperature effects at different humidities, i.e., the lines at different humidities are displaced and parallel.

RESULTS

Following determination of the rate constants and activation energies, and comparisons of the activation energies by means of a t-test, it was found that at the 0.05 confidence level no statistically significant differences existed between activation energies derived from data from humid ovens and those derived from data from dry ovens. This conclusion holds for all of the work analyzed, and is independent of the property measured. Thus, it must be concluded that testing in a dry oven will allow one to reach the same conclusions as testing in a humid oven.

It was also found that the activation energy determined by measuring the loss in mechanical properties of cellulosic materials, both paper and fabric, was about 27.3 ± 2 kcal/mole. This is in excellent agreement with other published reports (cf 13). It was also noted that, as expected, increasing relative humidity at a given temperature enhanced the degradation rate. Finally, it should be noted that the results of Ref. 14, shown in Fig. 3, indicate that an upper limit of 160 °C should be applied to the accelerated aging of cellulosic materials.

DISCUSSION OF RESULTS

It is to be expected that the activation energy should be approximately constant, even though different mechanical properties are measured. Consider the following for a system in which chemical changes follow first order kinetics. The time rate of change for a given property (P) which is temperature (T) dependent will be a function of the chemistry of the system (C) and some function, f(z), which relates the physical properties to the chemical state of the system: thus,

$$dP(T)/dt = f(C) \cdot f(z), \text{ and} \qquad (1)$$

$$dP(T)/dt = -kP \cdot f(z), \qquad (2)$$

where k is the rate constant.
Since f(z) is independent of time, (2) may be written as

$$dP(T)/dt = -AP. \qquad (3)$$

Equation (3) may be integrated to give

$$\ln P(T) = -At + a, \qquad (4)$$

where a is a constant.

The Arrhenius relation now becomes

$$A = A_o \cdot \exp[-(\Delta E/RT)], \text{ or} \qquad (5)$$

$$k = k_o^o \cdot \exp[-(\Delta E/RT)] \cdot f(z). \qquad (6)$$

If f(z) is independent of temperature, the activation energy will not be affected by the property being measured. Since the function f(z) is unlikely to always be completely time and temperature independent, we should be prepared to accept slight variations in the determination of activation energy, no matter how carefully we control our experiments.

As a corollary to the above, it should be noted that we cannot predict the actual lifetime of an object at ambient conditions from accelerated testing since we do not know f(z) as a function of temperature. Furthermore, since the time required to measure f(z) as a function of temperature approaches the lifetime of the material as the temperature is reduced, it is unlikely that we shall ever be able to predict lifetimes. It is, however, possible to measure relative effects. Thus, we can determine that a particular treatment can enhance the lifetime of an object by some factor, but not by a given number of years.

CONCLUSIONS

From the above we may conclude that:

(1) accelerated aging of cellulosic materials may be conducted at temperatures up to 160 °C in either dry or humid ovens without affecting the conclusions,

(2) that precise control of temperature and humidity at the chosen conditions is more important than the choice of conditions,

(3) that the choice of physical or mechanical property to be measured will not alter the conclusions, and

(4) that attempts to predict actual lifetimes rather than ratios are not warranted by our present knowledge.

ACKNOWLEDGEMENTS

The author wishes to thank the National Museum Act, administered by the Smithsonian Institution, for its generous financial support and Mrs. Hye Kyung Kim for her help in the experimental work.

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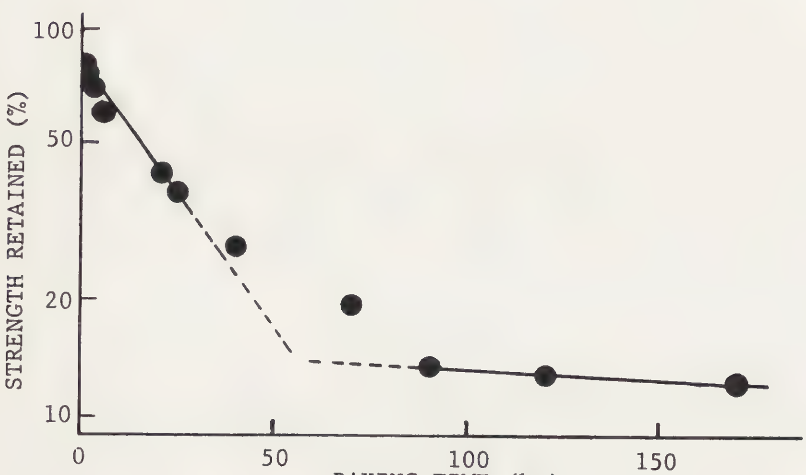

Fig. 1: Aging curve at 150 C for rayon cloth from Ref. 2.

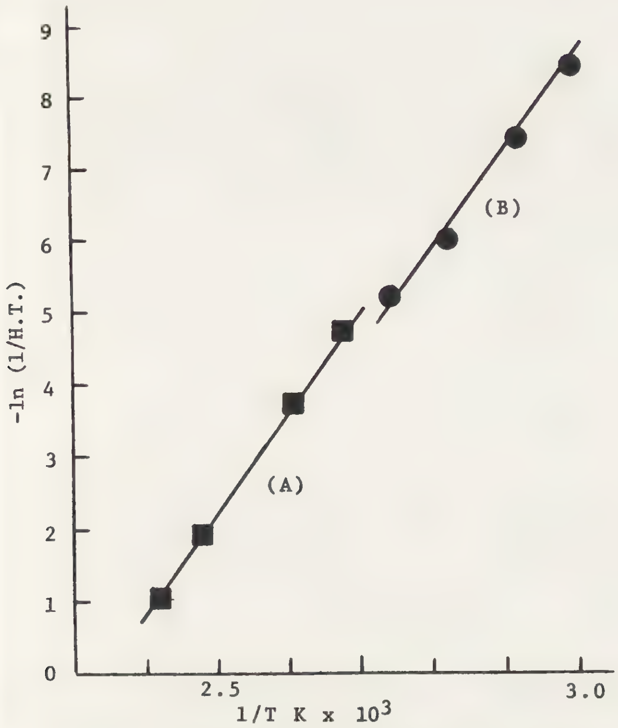

Fig. 2: Arrhenius plot of the reciprocal of the half-life (H.T.) vs. the reciprocal of the temperature for the data of Little (A) at 1% moisture regain and Graminski, et al (B) at 60% relative humidity. Temperature range is from 60 to 150 C.

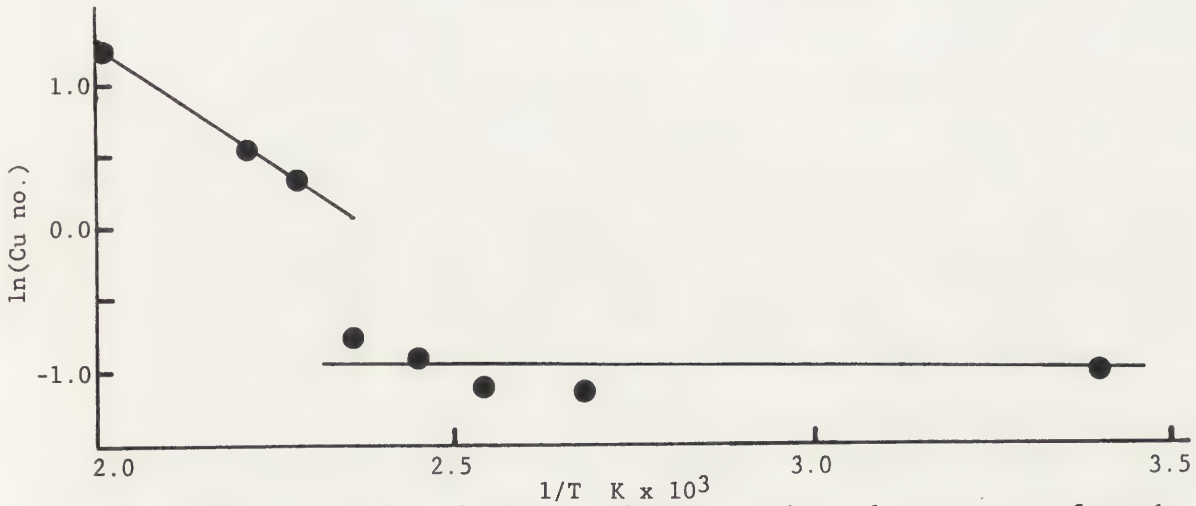

Fig. 3: Arrhenius plot of copper number vs. reciprocal temperature from the data of Ref. 14.

IRON STAINS ON TEXTILES : A STUDY TO DETERMINE THEIR NATURE AND TO EVALUATE CURRENT TREATMENTS

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SUMMARY

Of great concern to textile conservators is the ever present range of yellow, orange and brown stains, most commonly observed on white or light coloured textiles and which are generally described as 'iron stains'.

While being aesthetically unpleasing, no published studies of these stains have yet resolved the problem of whether or not treatment is required; or have provided details of their nature or degradation factors. Treatments currently recommended have been found to be ineffective in many cases or causing only a temporary effect.

Research is, therefore, being conducted to identify, classify and analyse these stains on textiles; examining also their close relationship to similar stains on paper and to corrosion science.

Preliminary results of the research are recorded. To date it has been possible to describe and analyse four basic stain types for which non-destructive methods of identification are described.

It is hoped that an understanding of their nature and degradation processes will aid in the examination of the causes and development of these stains; and subsequently the formulation of preventive methods for textiles in long term storage.

The necessity for treating each of the categories of stains so far described, or providing means to stabilise the degradation is being investigated in conjunction with a re-evaluation of currently recommended treatments.

INTRODUCTION

For many years I have been concerned that very little is known about the yellow to orange stains which appear on textiles and are collectively known as 'iron stains'. One assumes that in the formative years of textile conservation these stains were analysed and appropriate treatments devised, however, there is no documentary evidence of this.

The conservation literature on these stains is negligible, however many references can be found in the 'household hints' section of cookery books, particularly those written in the 19th century.[1] It is interesting to note that such stains are described quite distinctly as 'iron rust' and 'iron mould'. Iron rust was presumably any stain which could be considered to be an iron contact stain, and iron mould was described by one 1867 source as being "a fungus which feeds on the protein in fibres, particularly on starch" [2]. Many treatments were devised for these stains with a particular predilection being for acidic treatments using a range of acids - lemon juice (known as citric acid) - salts of sorrel (oxalic acid) - and muriatic acid (hydrochloric acid). In all cases great care was exercised in the neutralisation of the treated area subsequent to careful washing. Alkaline treatments were also used and these ranged from salt and baking soda to chloride of lime, an early chlorine bleach.[1]

In paper conservation the same coloured stains have historically been described by the collective name of foxing, and likewise have a lengthy history. One source of 1891 states that "a fungus must always be present in these spots" [3] which suggests a connection between this information and that describing 'iron mould'.

The basis of my work has, therefore, been the belief that both in Paper and Textile conservation we are indeed dealing with the same stains. The hypothesis is that there are two distinctly different types of stains which are common to paper and textiles (in particular the cellulosic materials). These are:

Iron stains (or iron rust) which are formed as a direct consequence of the oxidation of iron in the presence of moisture; either by contact with an iron object or being formed as a result of particles of iron deposited on or in the item through washing, commercial production methods or from blood, etc.

These stains usually appear bright orange/yellow in colour, or rich orange/brown, however, in severe cases of iron impregnation, the stain may appear a dark reddish brown. Degradation of the fibres within the stained area is common, with the weakest and most vulnerable areas being associated with the darkest colouration.

Foxing (or iron mould) is generally described as a fungal related stain, with or without association with iron. Characteristic light yellow to orange, or dull brown diffuse stains occur. I am, however, not aware of any reports, nor have I personally observed disintegration of foxed areas, such as experienced with iron stains.

The literature to date, concerning the nature of foxing, has, however, been rather contradictory. Meynell and Newsam in 1978 stated that the stains they examined showed no more iron than the surrounding paper, with fungal hyphae being present in most stains, so they suggested iron could not be deemed a factor.[4] In 1982, however, Cain and Miller reported that of the 43 stains they tested only one was found to have a fungal hyphae, all the others contained iron particles or iron rich sites in contrast to the surrounding paper which was iron free.[5] I propose that each of these reports documented different stains; this being consistent with my preliminary investigations on textiles (see later).

We therefore appear to have two types of foxing:

- a fungal growth formed in association with iron; with iron being the substrate attracting the fungi,[5, 6] and

- a fungal growth with no iron present, the fungi being attracted by some other substance such as chlorine or starch, for example.[3, 7, 8, 9,]

Both of these types may produce stains in a number of ways:

(i) As a result of quinones (the colouring matter of some fungi) which may act as dyes. These are consequently difficult to remove, and even more so if iron is present as this will act as a mordant.

(ii) There are also authorities who believe that some types of fungi associated with foxing may be invisible or barely visible until they die, at which time oxidation takes place and then gradually the characteristic stain appears.[10] This seems probable, and may also account for Meynell reporting that he found no foxing stains less than 23 years old.[3] Certainly there are many stains which fluoresce under UV light which are not visible to the naked eye.

(iii) Amongst experts I have consulted on this type of fungi, there has been the common thought that bacteria could play a part in the formation of these stains, either by promoting the colouring matter or by acting as a suitable substrate for the fungi.[11] This is one aspect being investigated.

(iv) I have also come to believe, from my observations, that some stains may develop photochemically.

TREATMENT OF 'IRON STAINS' ON TEXTILES

My main concern is that the treatments so far recommended for eradication and/or visual removal of these so called 'iron stains' on textiles, may in many cases be inappropriate, particularly where stains contain no iron.

Three standard treatments have been constantly in use now for the last 10-15 years; oxalic acid and hydroflouric acid as individual spot-treatments, and disodium EDTA for treatment by submersion. In Australia, hydroflouric acid has rarely been used due to its highly corrosive nature and the danger to the user, however oxalic acid and disodium EDTA either as separate treatments or one followed by the other, have proved to be effective treatments for the visual reduction or the apparent removal of some stains. There are stains, in both classifications, which exhibit little or no response to these treatments. I have intentionally used the phrases - visual reduction or removal because in many cases this is all that has apparently been achieved since the stain will sometimes reappear in as little time as two months. Sometimes the reappearing stain is not in the same visual form, and in many cases where spot treatment has been used there is a distinct yellowish halo which is indicative of some element of the stain having been solubilised and dispersed, or of fungal attack.

This is of particular concern when the philosophy in this field of conservation is for each item to undergo only one treatment in its institutional lifetime.

IDENTIFICATION AND CLASSIFICATION OF STAINS

Following my preliminary observations, the first stage of the project has been the identification and classification of the stains, initially using non-destructive methods followed by destructive analysis. This work has indicated that we are not dealing with one or two types of stains but in fact three main types, with each having sub-types. The main types are; <u>iron contact stains</u>, <u>fungal stains with no iron present</u>, <u>fungal stains in the presence of iron</u>.

Once there is a realisation that there are a number of stain types, there is a requirement for a non-destructive means of analysis, and this is one of the main aims of the project. It should, however, be noted that in order to have meaningful results only old textiles can be used, and these must also be able to undergo destructive analysis to confirm the non-destructive results.

With the possibility of being able to determine different stain types the conservator will be able to select an appropriate treatment and therefore minimise the risk of any recurrence of the stain or of any deleterious effects to the item undergoing treatment.

The methods so far found to be of value in the identification of these stains are:

(i) Visual identification
(ii) UV identification
(iii) pH tests
(iv) Spot tests for iron

(i) <u>Visual identification involves</u>:

- examining the colour, and recording the colour using Munsell Colour Charts. I have found that colours do tend to be specific to certain categories of stains. (as previously described)

- looking at the shape of the stain, in particular, whether it has hard or diffuse edges, or intense staining in the centre etc., and

- using a stereo microscope to examine the surface of the stain, this will particularly aid in the identification of iron stains where surface accretions may be examined.

(ii) <u>The identification of stains by UV</u> may be one of the best means of determining stain types. Under UV fluorescence, iron reflects a dark reddish black colouration, whereas fungi reflects a bright white colour. Initially a UV light source with a wavelength of 360 nanometers should be used to examine the item. This will clearly indicate areas of staining and is relatively safe to use. A wavelength of 250 nanometers will produce a more distinct fluorescence but this is quite dangerous if used without the correct safety precautions.

Using UV fluorescence I have to date found four distinct types of stains, three of them conforming to a large extent with the information available relating to foxing on paper - in particular the recent report by Cain and Miller.[5] These are:

Type 1. Intense yellow to orange or dark reddish brown stains, often having a well defined edge or perimeter mark. Under UV these fluoresce a very dark intense reddish black, which confirms the presence of iron. These stains may also appear in the shape of a cross.

Type 2. Stains which visually have diffuse edges and a dull brown/orange colour do not appear to

fluoresce under UV, however, as the surrounding fabric fluoresces, some stains which were only faintly visible under normal light are more noticeable. A few of these stains have been analysed using SEM and all show the presence of fungal hyphae and most show the presence of minute traces of iron.

Type 3. Where the stains appear similar to those described as Type 2, but have a noticeably darker centre and often a lighter diffuse perimeter, it is common to find that beyond the visible perimeter of the stain there appears a bright whitish fluorescent area when subjected to UV radiation. This in particular indicates the presence of fungal activity.

Type 4. Stains which are very pale diffuse yellow and, often barely visible under normal lighting conditions, appear as larger areas of bright white fluorescence with UV radiation. This confirms fungal activity.

All the observations have been confirmed with the use of a SEM.

(iii) The use of pH as a means of determining the presence or type of fungi is recommended by Kowalic [12] and other authors. This, however, seems to be of little value in these circumstances as the type of fungal activity or iron stains we are concerned with have very similar pH ranges (that of pH 4-5). pH could, however, be useful as a basic means of determining whether the conservator is dealing with a foxing or iron stain as opposed to some other stain type exhibiting the same colour.

(iv) Spot tests for iron I believe present a very quick and simple means of confirming the presence of iron following its initial identification through UV examination. I have examined methods used by metal conservators[13] and also the methods cited by Cunha for the identification of iron in inks and I have found one method which is particularly good - being non-damaging to the textile and accurate in determining even minute traces.[7]

For this a 5% V/V solution of acetic acid in distilled water is used, one drop of which is placed on the stain. The tip of a piece of filter paper is then placed over the stain and held there for 15-30 seconds. A drop of 1% W/V solution of potassium ferrocyanide is then placed on to that area of the filter paper, which produces a blue colouration if iron is present. Only on the faintest stains on the most sheer fabric did this not produce a positive result.

The tests I have described are all simple and non-destructive, and they employ facilities which are available in all laboratories. Work is continuing to refine these methods and to further confirm the results and the hypothesis.

To date the confirmation of these non-destructive tests has been with the use of the Scanning Electron Microscope, however, other techniques will be used such as X-ray Diffraction and Infra Red Spectroscopy to analyse the state in which iron is present. This is important with respect to the satisfactory treatment of stains containing iron, since current treatments may not be suited, in all cases, to the removal of some particular forms of iron. It is also possible that a more stable and less soluble iron compound may be formed when both iron and fungi are present.

CONCLUSION

In conclusion I believe that research to date concerning the nature of iron stains and foxing has indicated that there are three main types of stains to be considered:

(i) those caused by the presence of iron, in solution, or by direct contact with an iron object

(ii) those developing following fungal activity associated with the textile or paper fibre or other substrates such as chlorine or starch, etc. and

(iii) those developing following fungal and/ or bacterial activity in association with an iron deposit.

To assist in the classification of such stains a number of identification methods have been proposed, these being:

(i) visual identification

(ii) UV identification

(iii) pH tests

(iv) spot tests for iron

Treatment of these stains without first determining their precise nature may result in an inappropriate treatment being selected. The consequence of this being a seemingly ineffectual treatment, reoccurrence of the stain, or possible degradation of the stained area.

A further phase of this project is to evaluate current methods of treating such stains and to categorise these in respect to the various stain types. I will also be examining the requirements for new treatments to be devised.

Concerning the further testing and examination of these stains and confirmation of results by destructive analysis, I would be grateful to anyone who can provide me with samples of the various stain types on textiles.

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PAINTED TEXTILES

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ABSTRACT

This paper considers the problems raised by the conservation of painted textiles, and discusses several areas of interest: the cleaning of painted textiles, the choice of consolidants, and the materials and techniques used in painting on textiles.

INTRODUCTION

The Textile Conservation Centre has conserved a variety of painted textiles, which have posed problems hitherto outside the field of textile conservation. Being a mixture of painting and textile these objects do not fall into any of the traditional conservation categories, as a result painted textiles have been treated by specialists in either painting or textile conservation. Because of this the Textile Conservation Centre has recently begun to research into the practical application of both painting and textile conservation treatments to these objects.

A precise definition of objects considered to be painted textiles is difficult to achieve - for the purpose of this paper we are only considering textiles decorated by hand with a paint i.e. pigment suspended in a medium. This will exclude those textiles which have been decorated by hand but with dyestuffs, for example, Indian chintzes and printing as a whole. At the Textile Conservation Centre we have treated military, trade union and heraldic flags and banners of varying ages and sizes. We have also been involved with the conservation of a sixteenth century stained cloth, costume accessories, painted embroideries and ethnographic objects.

The conservation of these objects almost invariably leads to problems in the choice of treatment. The painted textile must be treated as a whole, with emphasis on both painted and textile components. However, in practice this is difficult to achieve without the necessary background research into specific problems such as the effect of wet cleaning on painted surfaces (let alone the effect on the combination of paint and textile).

WET CLEANING PAINTED TEXTILES

The wet cleaning of textiles has often been found to be beneficial to their long term preservation, however, wet cleaning is only undertaken following numerous tests to ascertain the safe application of this treatment. The additional complication of the simultaneous treatment of such dissimilar substances as paint and organic fibres has yet to be fully researched. The problems will probably be centred around the basic differences of structure, with (for example) differential swelling of fibres and paint films leading to delamination. The complexity of any paint film raises further problems when size layers, grounds and varnishes have to be considered for their moisture sensitivity as well.

The Textile Conservation Centre has wet cleaned a number of painted silk banners. During this process the basic paint/fabric adhesion did not generally cause problems. However, tests carried out on an object where the fabric support was linen showed that it was not possible to wet clean due to the condition of both fibre and paint.

CHOICE OF CONSOLIDANTS

Consolidants must be chosen with certain criteria in mind. Among those considerations that we might list, the following are probably the most important:

1. Application without impregnation, or without staining or discolouration of the textile.
2. Retention of textile properties.
3. Stability.

The requirement of (1) is obvious. The second criterion implies a relatively strong consolidant which will be active even with very thin films. Finally stability is necessary not for reversibility (which is unrealistic for a consolidant in this situation) but to ensure minimal changes in flexibility and colour. Painted textiles are an extreme test of any adhesives' mechanical properties and in choosing one we are going to be particularly interested in high peel and sheer strengths, combined with good flexural qualities.

We have tested a number of consolidants for their suitability under these criteria but have not found any satisfactory in practice.

MATERIALS AND TECHNIQUES

As a part of our work on painted textiles, we are beginning to make preliminary studies into the materials and techniques of painting on textiles. These researches are being centred on two aspects - the relevant documentary sources, and the scientific analysis of the structure of those painted textiles brought to the Textile Conservation Centre for conservation.

There are only a limited number of documentary sources available in England, apart from the traditional treatises on the art of painting. Some of the banners that we examine come from trade guilds, and the records of these guilds can be revealing by way of payments to artisans or for materials.

The technical examinations of painted textiles will give us valuable information on how to treat these objects. For example the type or presence of a ground layer may be highly consequential in the subsequent choice of treatment. In certain cases consideration may be given the removal of a varnish layer, if present.

CONCLUSION

As we said in our introduction, this is a new area of research for the Textile Conservation Centre. We are aware that other conservators have experience in this area, but as yet little has been published as either research/analysis or case histories.

Although we have treated a variety of items, we have only recently begun to look into this field. We hope that other conservators with experience and/ or interest in painted textiles will be willing

to share their thoughts and experiences. Therefore, we should like to propose regular contact, perhaps in the form of a newsletter. Both case histories and research findings could then be made available to all who need this information. Anybody who is interested is invited to contact us at the Textile Conservation Centre.

TRAINING TEXTILE CONSERVATORS

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ABSTRACT

The Three Year Postgraduate Diploma Course in Textile Conservation held at the Textile Conservation Centre at Hampton Court Palace in conjunction with the Courtauld Institute of Art, University of London is divided between the Centre and the Courtauld Institute. Four to six students are offered places each year in a 50/50 ratio of British to foreign students. Graduates are generally offered museum posts but are expected to consider the merits of any conservation post offered to them including teaching posts.

Posts now held by graduates include positions as conservator/tutors curatorial positions with preventive conservation responsibilities, setting up and running museum and Area Museums Service textile conservation departments and the training and supervision of volunteers for Historic Houses.

The first formal structured course in textile conservation held in conjunction with the Courtauld Institute began in 1973. In 1975 the Textile Conservation Centre came into being and Grace and Favour accommodation was offered within Hampton Court Palace for the purpose of teaching.

The course lays emphasis on preventive conservation science and teaching the investigative methods necessary to proper record keeping. Practical experience is gained under the guidance of the Centre's Scientific Advisor and Conservator Tutors by working on historic pieces of every kind and shape including archaeological and ethnological examples.

Introduction

We often hear phrases like "seeing things as they are" which should perhaps always be qualified to mean "as we believe they are at the time of seeing them". The study of our past is a pastime of surpassing ambiguity, much influenced by the material available for research and how this material is presented according to the knowledge and experience of the presenter who may also be influenced by the state of preservation of the objects studied, and the societies represented by either the objects or the presenter.

In order to recognise special constructions the conservator needs to have a good knowledge of the history of art and technology and in order to record what he finds and to devise the safest form of both remedial and preventive conservation the conservator needs a vocabulary shared by the owners, the historians and the scientists with whom he undertakes the responsibility of preserving our cultural heritage. In other words conservators need an overlapping knowledge for the purpose of understanding the functions of the three parts of the triangle of interested groups:

Conservators - Scientists - Historians

each representing enormously large subjects with each subject demanding many years of study.

To work effectively, we must work in unison, because specialist knowledge should make for specialist discoveries and unless we work together we may between us lose too much of the knowledge we seek to preserve to make a coherent whole.

Review

The Three Year Postgraduate Diploma Course at the Textile Conservation Centre with the Courtauld Institute of Art, University of London, has been put together to provide textile conservators with the knowledge and skills for competent textile conservation and the vocabulary necessary to promote easy collaboration with colleagues in other areas of the Museum Service. In a field as diverse and complicated as this, training is obviously of the greatest importance in ensuring the success of any collaboration.

For the purpose of treating textiles as historic documents it is obviously necessary to begin by training textile conservators to know not only what they should do but why they should do it. We all use the precept that conservation should not interfere with any evidence from the past, we ought to add that we should also consider those aspects we have not as yet the means to decipher. Bear in mind the relatively short time in which we have come to rely on science and advanced technology for our investigations and then imagine what the future may hold in store. Different materials demand different treatments and conservation need conservative conservators trained to devise individual treatment for each object according to its composition, condition and place in history.

These points made me concentrate on using the unifying factors of textiles as the basis for teaching. That is to say the common denominators of all textile objects - fibres, dyestuffs and finishes, their reactions to past and present conditions and treatment depending on their juxtaposition, former repairs and the purpose and use for which each object was created. The Textile Conservation Centre's reference collection gives students opportunities to conduct controlled experiments on actual textiles of various ages and origins.

First Year

In the first year the formal very structured programme of lectures and seminars provides the framework for an understanding of the range of problems a textile conservator might encounter.

Special emphasis is placed on the importance of preventive conservation and how the survival of objects may be dependent on local climate and customs as well as on the application of conservation science.

The practical work includes the handling, examination and documentation of objects together with the necessary introduction to conservation science and practises - dyeing and laboratory experience that enable the students to evaluate the problems presented.

During the first year, students also receive a wide rangeing introduction to textile technology and techniques and to the basic construction of the many types of embellishments that have been produced by textile artists to enhance our dress and our surroundings.

Second Year

During the second year, students continue to x expand their knowledge of conservation in relation to the physical conditions of each object under treatment, which is also researched for its cultural and technological significance before treatment may be applied in accord with the results of this research.

Third Year

During the third year students undertake a special research project. A detailed report is presented on the problems that they encountered, an assessment of those problems in relation to treatment and the completion of the project as a whole including documentation.

Throughout the course the students gain practical experience of conservation techniques by working on historic textiles under close supervision by the Textile Conservation Centre teaching staff and by its science tutor.

Comments

The course has now been running for 11 years. Since its initiation it has been lengthened, the teaching has become more intensive and the examinations more exacting, however the outline remains essentially the same.

The diversity of the projects undertaken gives an indication of how the knowledge of textile design and technology, as well as textiles themselves have spread across all international borders for as long as we can trace. This universality is echoed by the Centre since it has been housed at Hampton Court Palace.

Through undertaking conservation commissions the Centre has been able to promote a closer collaboration between client museums tutorial staff and students. The resultant exchange of ideas and information has proved mutually beneficial.

It is tempting from the point of view of establishing general conservation training to label objects made with fibres simply as objects with an organic content but perhaps the time has come to consider the implications of the size of the subject as a whole and accept that historic textiles are unique and therefore difficult to fit in with any other material or conservation discipline.

Implicit in the teaching offered by the Textile Conservation Centre in conjunction with the Courtauld Institute of Art is that the objects like any other document of history are seen as links in ever extending chains of knowledge.

REGENERATED CELLULOSICS: THEIR FABRICATION AND FINISHING BEFORE 1940

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Summary

This paper outlines the processes used before 1940 in manufacturing and finishing regenerated cellulosics. The diverse and experimental nature of the treatments is described both to provide a foundation for understanding the observed degradation of man made fibers, and to predict the consequences of conservation treatment.

"The discovery of 'artificial silk' has always been regarded by the lay public as one of the most wonderful inventions of modern times" (32) While this author had no idea of the size or importance of the polymer industry that would evolve from the rayon industry, when this was written in 1935, regenerated cellulosic fibers and films had already been commercially produced for 50 years. Consequently, present day textile conservators are caring for man made fibers that are a century old and in need of treatment. It is the aim of this paper to outline the types and characteristics of those regenerated celluloses produced prior to 1940, and to draw attention to those processing and finishing operations that can be expected to affect the longevity of objects made of those materials.

The earliest written speculation concerning artificial fibers occurs in Robert Hooke's 1664 Micrographia (30) in which the author predicted the synthesis of a material like silk. Silk was in fact the model for all early fiber research. Cotton cellulose was the usual raw material and although it was comparatively cheap, processing added significantly to the cost of the fiber, making it necessary to sell the product as a luxury fabric. Silk was the obvious choice, and so the new fiber was treated.

Experimental fibers were made from mulberry twigs and nitric acid in both 1832 (Braconnet's "Xyloidine") and in 1853 by E. J. Hughes, but a commercially viable product was not developed until the early 1880's. In 1883, Sir Joseph Swan received English Patent 5,978 (29) for an artificial silk he made by coagulating a solution of cellulose nitrate in glacial acetic acid. This denitrated fiber found its initial use as the filament used in the first electric lightbulb. The first artificial fiber used for textiles was made by Count Hilaire de Chardonnet at Besancon in 1884 (30). This product, a cellulose nitrate dissolved in alcohol and extruded into warm air, was called Chardonnet and is generally considered the first rayon. Rayon is defined broadly as any regenerated cellulose, and more strictly as "manufactured fibers composed of regenerated cellulose in which substituents have replaced not more than 15% of the hydrogens of the hydroxyl groups". (1)

A partner of Wardle and Davenport, Ltd., the first British manufacturers of Chardonnet, describes the product as follows: "Chardonnet's yarn was, of course, of the nitro-cellulose or collodion type, and at first was highly inflammable and brittle. It had a high metallic lustre, and a hank of it felt more like a lump of lead than a skein of silk. Often, in winding, there would be nine pounds of waste out of 10 (sic) pounds of yarn, but, for all its defects, the demand for it was so great that we could not get sufficient supplies." (29)

"Nitro-cellulose" is both the fiber's most common name and a misnomer, since the product is actually nitrated cellulose. Varying the degree of nitration changed the properties and thus the end use. A completely nitrated cellulose contains 14.4% nitrogen: cellulose-based explosives are 13.5% nitrogen, and those with 10-11% nitrogen are used to make an extraordinary variety of materials, the best known being fibers, photographic film, and lacquers. (36) When plasticized with camphor, it is known as Celluloid. The inflammability of the product was reduced by various denitration methods (27), but Johnson (28) has emphasized the hazard of storing these nitrated cellulosics.

The viscose process, still used to produce rayon, was discovered in England by Cross and Bevan in 1891. Wood pulp (or occasionally cotton linters) was purified, steeped in 17.5% sodium hydroxide, then aged (or "ripened"). Treated with carbon disulphide, it became sodium cellulose xanthate. After further treatment with sodium hydroxide and ageing, filaments were made by extruding the solution into an acid bath, drawing, and rinsing. (38) The rinsing includes baths to remove free sulphur, to bleach, and to neutralize the bleach bath. The degree of polymerization of viscose is dramatically less than that of cotton (300-500 vs 9,000-10,000) (30), and the difference in behavior was just as marked. Water sensitivity was a notorious problem with early rayons, with viscose both losing strength and increasing extensibility in water. (26,37) (Swelling behavior is in fact a means of distinguishing different types of the so called artificial silk.) (2) Considering that water caused swelling both laterally (26%) and longitudinally (5%) (38), it is easy to understand the attention given to improving the tensile strength and wet modulus of the fiber. This refinement was necessarily rather haphazard, because the chemistry of the materials was not well understood. Cellulose was intensely studied, but it wasn't until about 1926 that its molecular structure was determined.

The next rayon variant to become commercially important had actually been discovered in 1857. E. Schweitzer had observed that cotton linters were soluble in a solution of copper oxide and ammonia (known today as Schweitzer's reagent). Although the German firm J. P. Bemberg A. G. had started in 1891 to manufacture this new form, cupra rayon, the viscose process held sway until 1901, when E. Thiele delivered the viscose solution through wider spinning apertures into a slow-acting precipatating bath. When the filaments were stretched and then hardened in an acid bath, a finer, stronger fiber was produced. The company's name was used for this cuprammonium, and Bemberg silk was produced into the 1970's (3), with wood pulp replacing cotton linters as the raw material. This fiber offered a softer hand and improved wet and dry strength.

Esters of cellulose followed a course of experimental development parallel to that of the hydrated cellulosics. Schutzenberger made the first cellulose acetate in 1865, but manufacturing risks and difficulties were not overcome until the beginning of the twentieth century, when lacquers and "dope" for covering airplane wings were made from cellulose acetate. Fibers were made in 1913, but not produced on a large scale until 1921.

Cellulose acetate, or secondary acetate, is a wood pulp-based fiber in which up to 92% of the hydroxyl groups are acetylated. Cotton linters were used initially, but flax and ramie could have replaced them, had they not been so expensive. The pulp was dissolved in acetic acid and acetic anhydride, and poured into water, where it coagulated. The flakes were dried, then dissolved in acetone and extruded into warm air. Cellulose triacetate, in which not less than 92% of the hydroxyl groups are replaced by substituents, was produced experimentally in the early part of the twentieth century, but American production of Celanese Arnel was delayed until 1952 because of the expense and danger of the solvents. While triacetate was known to researchers in the firt half of the century, the small amount produced and its sharply different physical properties make it a matter for consideration elsewhere. Likewise, discussion of the cellulose ethers developed during this period is omitted because they are of greater historical than practical interest. (35)

From the foregoing discussion it should be apparent that the early production of man made fibers consisted of adapting and modifying the new fibers to impart properties that mimicked those of silk. Since the amount the fiber itself could be altered was limited, manufacturers depended a great deal upon finishes to modify the material. Then as now, finishing was the primary means of improving the appearance, hand, or utility of a fabric. The processes to which natural

fibers had been subjected could be classed as chemical or mechanical, and a survey of the literature shows that rayons were subjected to all the processes used on silk and cotton. The procedures were used in an attempt to improve rayon's low dry strength (and lower wet strength), and to correct shrinkage, dullness, uneven luster and dye penetration, and to reduce the fiber's sensitivity to light and chemicals. What was sought was a commercially satisfactory product rather than a long lasting one, and for those conservators charged with preserving these artifacts, a sampling of the finishing processes to which these materials were subjected will help identify the internal agents responsible for observed ageing behavior. Rayon's low resistance to mechanical processing necessitated an early reliance on chemical finishes. The chemical finishing processes considered below are divided according to whether they were applied to the solution, the yarns, or the fabric. Excluded from the discussion is a synopsis of the history of rayon dyeing.

Once the manufacturers were capable of producing a stronger, dependable fabric, research was directed to improving the fiber's appearance. The high luster, initially a desirable feature, fell out of favor, and attempts were made to deluster the fiber. The refractive index was first changed by introducing air into the solution to be extruded, but the further decrease in strength prompted an effort to find chemical additives. Mineral oil was used to deluster viscose, and, with less success, nitrocellulose. (23) Mixed into solution, the oil globules were drawn out in the spinning. The resulting filaments were semi-lustrous, but the addition of enough oil to dull the shine weakened the filament. The oil also increased the retention of free fatty acids from the soaps used in scouring, resulting in fabrics that became rancid in storage. Occasionally such delustered rayons retained so much of the soap that they developed a marked scroop. (21) Pigment was added to reduce luster, and when purified titanium dioxide became commercially available in 1928 (4), it became the delustrant of choice, although barium sulphate was also used. (22) Titanium dioxide permitted economical, uniform delustring except when used with fibers processed with glycerin. When exposed to light, the glycerin catalyzed the reduction of the pigment, which turned bluish or accelerated the rate at which dyes faded. (5) In passing it should be noted that solution dyeing of viscose was rare during this period. (7)

The treatment of the yarns themselves presented formidable technical problems, owing to their mechanical and chemical delicacy. Wet, swollen yarn had very poor resistance to stretching, necessitating extreme care in all finishing operations lest the yarn be permanently deformed. Subjected to a strong alkali solution, swelling was so extreme that the fiber appeared to dissolve. The fiber could be recoagulated by immersing it in an acid, but the strength and structure of such a yarn would be quite different from what they were before. Applying an acid to a rayon caused hardening and weakening.

The first step in treating a viscose filament was to remove the traces of the acid bath into which it had been extruded. This was accomplished by washing and drying. The product was grey-yellow and dull from the sulphur precipitated from the sulphuric acid that had been used to neutralize the caustic soda of the viscose solution. Removal was effected by treatment with sodium sulphide, washing, bleaching, and washing the fibers. Caustic soda and sodium carbonate were less commonly used in desulphurization. It was at the desulphurizing stage that the production of transparent paper ("Cellophane") differed from the production of rayon filament.

If the cleaned filament was to be used without blending, it had to be coated before it could be woven or knit into a fabric. Unlike silk, which contains a protective gum, pure rayon yarn requires sizing both for lubrication and for consolidation. The materials tried were: "preparations without number that have been mooted, recommended, and patented, some embodying mixtures of oils, solvents, waxes, and siccatives and varying in tenor from the presumably possible to the frankly ridiculous, some specifications indeed reading more like an alchemist's recipe than a modern preparation." (16)

Rayon was initially sized as if it were cotton, with starches, softeners, and gelatine, even though the last tended to promote mildew. Because the regenerated cellulosics absorbed less sizing than cotton, such treatment was only partially successful. For a time, a linseed oil solution was used to coat the yarns (9) but it could oxidize on the fiber, making removal difficult to impossible. The hardened oil was blamed for uneven dyeing and dullness. Various solvents and emulsions were tested, but the expense, risk, and yarn damage inspired experimentation with other sizes. Among them were waxes, gum tragacanth, and degraded or esterified starches. Early efforts to load the rayon occasionally resulted in oversized warps. Aside from embrittlement, the dust, "beading", and uneven dyeing caused by the size led to inferior goods. (12) Early synthetic sizes included a boric acid derivative of diethylene glycol, sodium borophosphate, a "protein degradation product in combination with oils and synthetic resins", phenol-formaldehyde resins, and polyglycerines. (14) All were easier to handle than the oil, because they were water soluble.

Often viscose and acetate fibers were blended with a natural fiber: with silk for stockings; with wool, for suiting; or with cotton, for yard goods. Of the three, the last two required the more processing to ensure compatibility between natural and synthetic fibers in the yarn. Wool/viscose blends were introduced in Germany during the first World War, in order to compensate for a shortage of raw materials. While the effort nearly ended with the war, attempts were made to put rayon waste to use. Predictably, fibers designed to mimic the smooth, lustrous qualities of fine silk failed to mix well with rougher, crimped wool. Eventually, a slightly modified rayon fiber was mechanically processed to impart wool-like quality . (18)

Viscose fibers were blended with cotton for both knit and woven goods. To overcome the incompatability between the viscose and the cotton fibers, the rayons were mercerized. Ordinary cotton mercerizing processes severely damaged the fibers of regenerated cellulose, consisting as they did of aqueous treatment of a yarn or fabric under tension, using hot, strong solutions of approximately 20% sodium hydroxide. The mercerization was employed to help equalize the dye affinities and luster of the two types of fiber. Caustic soda was used, but manufacturers discovered that different types of regenerated cellulosics had different alkali sensitivities. Viscose that had been desulphurized was more resistant than that that had not, and cuprammonium was readily attacked. (10) While a certain loss of tensile strength was inevitable, efforts were made to mitigate the damage by adding such materials as sodium acetate to the baths (21), by mechanically modifying the yarn (13), or by altering the rinses to reduce swelling and alkali retention. Acetate of course could not normally be subjected to strong alkali solutions, lest it saponify, but such a treatment was investigated in an effort to reduce acetates' heat sensitivity. (19)

Once the yarn was woven or knit into fabric, the first step was to remove all the oils and sizes that had been applied to facilitate construction. Desizing or degumming operations varied according to the size applied, and according to whether natural silk was blended into the yarns. Starches on cellulosics could be removed enzymatically, if particular care were taken not to mishandle the wet fabric. Alkali sensitivity caused strength loss when pancreatic acids were used to desize blends. (14) Proteolytic enzymes such as papain required activators that were either poisonous, expensive, or commercially unavailable. These were replaced by sodium thiosulphate and sodium hydrosulphite in an acidic bath. Dry-cleaning solvents - which were benzene and gasoline at the time - removed waxy sizes, and soap and water were used for (new) linseed oil or gelatine size. Both linseed and gelatine could be very difficult to remove entirely.

It was occasionally necessary to bleach those fabrics that were intended to be very white or brightly colored. Sodium hypochlorite, peroxide, or a mixture of the two were used. (8,37) Loss of strength and luster were risks inherent in the process.

In what might be considered a fabric sizing process, some goods were either weighted or scrooped. In a procedure reminiscent of that used to impart bulk and weight to silk, rayon fabrics were immersed in baths of metallic salts. As its name suggests, weighting made the fabrics heavier, increasing the cover of a light one. This of course was less expensive than weaving a heavier product. By loading and swelling a viscose or acetate with cheap organic or inorganic materials, production costs were diminished and the less expensive product could be more widely marketed. As with silk, salts of tin, zinc, aluminum, or zirconimum were employed (20), and, of course, a strength less

comparable to that suffered by silk. In addition, the dyeing properties and luster of such goods were markedly altered.

Like silk, rayon was sometimes treated to impart scroop, which is defined as the . . ."peculiar rustling or crunching sound noted in certain rayon and silk fabrics". (15) Small amounts of organic acids (such as formic or acetic) were used, but if they were applied directly to the fabric, the high heat used later in pressing caused the rayon to carbonize and powder. (24) It was found that soaps have a great affinity for regenerated cellulosics, and that the organic acids had a higher affinity for the soaps than for the fabric. Thus by washing the goods, the residual soap could provide a protective coating. Finally, after dyeing, the regenerated cellulosic fabrics were subjected to an assortment of finishes designed to impart particular "end use" properties. Although many were still of the "alchemical" sort, they are mentioned to alert conservators to the purposes if not the exact compositions of finishes on historic fabrics. Fireproofing, waterproofing, and creaseproofing were all undertaken before 1940.

Fireproofing materials were necessary for viscose, cuprammonium, and nitro rayons. Acetate melted rather than burned and, since the melt restricted contact between the fibre and oxygen, prevented combustion. An acetate solution was in fact applied to rayon fibers as a fireproofing agent. Mixtures (many with starches) containing potassium or aluminum tartrate or sodium tungstate, sulphate of ammonia or ammonium borate, or Epsom salts (with or without borax) were applied, although none was particularly fast to laundering. (2) A. N. Hay describes a preparation of calcium phosphate, borax, molasses or dextrin, and waterglass. (25) The coloring of fireproofed fabrics could be accidentally altered by the powdery deposit, the increase in moisture because of the hygroscopic precipitate, or the pH of the solution required to apply the materials.

Waterproofing and creaseproofing were both accomplished using "resins". (One author comments that "All known compounds can be used as synthetic resins.") (17) Waterproofing agents could include fats, soaps, waxes, oil (linseed or otherwise), and starch. Some of the associated problems are discussed above. When fabrics rather than yarns were treated, they could become yellow, sticky, stiff, or airproof. They did reduce the water permeability, and had the added advantage of increasing dimensional stability. One therefore finds them used for shrinkproofing and creaseproofing as well, although research on these problems was already focussing on the formaldehyde-based resins, which are still in use. (33)

The factors influencing the rate and nature of the ageing of rayon are clearly quite complicated. Not only the material itself, but the various finishes respond in different ways. A knowledge of the processing of the fibers will facilitate understanding of the factors contributing to decay, making it possible for conservators to consider and treat the sources rather than the symptoms of decay.

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ELUCIDATION OF POSSIBLE APPLICATION OF MODIFIED GLASSES TO PROTECT MUSEUM FABRICS AGAINST PHOTOAGEING

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SUMMARY

The protective effect of some modified glasses used to protect museum fabrics against photoageing is studies. Spectra for glasses in the visible region of the light spectrum and data on the ultraviolet and infrared radiation transmission are presented. The authors have studied the ageing of samples of the fabrics dyed by unstable dyes and exposed to the light radiation from various light sources screened modified glasses as well as by an ordinary window glass.
The obtained results have indicated efficiency of application of modified glasses for the purpose of protecting art fabrics in the museum practice.

It is common knowledge that the least durable art materials kept in museums are fabrics. Fabrics experience both mechanical damage and discoloration of the dyes which were used when these fabrics were manufactured. The decisive factor contributing to fabric ageing is the light radiation both from the Sun and from artificiallight sources. Therefore, protection of museum fabrics against the destructive effect of the light radiation is one of the problems of current interest. To this and, the articles made of fabrics are protected from the light flux by using curtains. Recently, however, a new method has emerged to protect the works of art kept in museums from the destructive action of light.
The spectrum of both natural and artificial light consists of the visible, ultraviolet, and infrared regions. For the exposition purposes, we need only the visible portion of the light spectrum. The ultraviolet and infrared radiations are absolutely unnecessary here and, what is more, they may prove only harmful to pieces of art. The ultraviolet rays cause primarily photochemical processes responsible for the ageing of works, while the infrared radiation has a thermal effect and, hence, contributes to faster ageing.
Along with ordinary window glass, the domestic industry manifactures also glasses with a reduced transmission factor in the ultraviolet and infrared regions of the light spectrum. This is achieved either by coating the surface of the glass with a metal-oxide film or by specific electrochemical painting of glass surface, or by introducing certain admixtures to the charge of a glassmaking furnace.
The ageing process can be made to slow down and the life of works of art can be extended if we use such glasses to screen them from the incident light.
In the Material Testing Laboratory of the Grabar Conservation Centre, we studied 14 types of glasses which have been modified by all the above methods.
We have studied their optical and chromatic characteristics because the glass in showcases, window openings, or enclosures of art works themselves must not introduce any optical or chromatic distoritions during exposition. The preliminary investigation made it possible to choose, for further studies, a gray electrochemically painted glass, glasses dyed in the mass, and glasses manufactured by a combination of these methods, since they meet the exposition reguirements. The glasses coated with metal oxides and the electroche - mically treated glasses, which differed substantially from ordinary window glass in terms of the spectrum of visible light transmission, proved to be inadequate because they introduced optical and chromatic distortions.
Spectra of glass transmissions in the visible region of light radiation intended for further use, were recorded with a SF-10 spectrophotometer. They can be seen in Graph I.
We have also determined transmission spectra of these glasses for the ultraviolet and infrared. We have experimented to ascertain the changes in the light flux in the ultraviolet (280 to 380 nm) and in the heat flux after their transmission through modified glasses. It turns out that ordinary window glass transmits over 37 % of the near ultraviolet radiation, whereas modified glasses are transparent only to 9 to 30%.
It was shown experimentally that modified glasses are superior to ordinary window glass in the reduction of the heat flux. We have es tablished this fact from temperature measurements taken behind the screen made of a given glass and irradiated by an infrared source (see Table I).
But to elaborate recommendations concerning the application of modified glasses to protect works of art, it is ansufficient to confine oneself solely to study of their transmission spectra for any particular region. It is because the processes of ageing of art materials have been poorly investigated up to now. For this reason, we are not able to make well-found predictions regarding possible effects of the spectral characteristics of a protective glass, irradiated by different light sources, on the rate of ageing of one or another material.
Our earlier experiments were aimed at studying the protective action of modified glasses in the ageing of watercolor and oilcolor paintings exposed to various light fluxes, namely: natural sunlight, xenon lamp (whose spectrum is close to that of natural light), mercury-quartz lamps, and luminescent lamp providing a highly-ultraviolet light flux. The results if these studies were reported earlier. We sholud like only to stress here that these findings allowed us to recommend some modified glasses for the protection of the art materials against the destructive components of light radiation. These include a gray electrochemically painted glass, a gray mass-dyed glass, a blue mass-dyed glass, and a HAG-type glass absorbing substantially in the three regions of the light flux. All these glasses are made at the Saratov glass works.
To clarify further the question of museum fabrics protection, we have lately undertaken special experiments on which we are going to concentrate now.
Museum fabrics are aften dyed by unstable organic dyes. Prior to the dying, fabrics are treated with specific compounds. The fabrics pretreated in this manner are no longer lightfast and call for special protection against light radiation.
The experiments were carried out on samples of silk which had been dyed as follows. Samples were treated with potassium alum or iron sulfate at 45°C for half an hour and then they were dyed with buckthorn or tansy extracts.

We used the following symbols for samples:

Materials used for sample treatment	Symbol
Potassium alum and buckthorn	PAB
Potassium alum and tansy	PAT
Iron sulfate and buckthorn	ISB
Iron sulfate and tansy	IST

All the kinds of samples underwent an accelerated laboratory ageing over 300 hours under the following light sources:
(1) a mercury-quartz lamp (the distance to the sample being 50 cm),
(2) xenon lamp (the Xenotest apparatus),
(3) filament lamp (200 W, 25-cm distance),
(4) LB-type white luminescent lamp.
To control the change of samples, we plotted lightreflection curves with a SF-10 spectrophotometer over the wavelength range extending from 400 to 750 nm prior to accelerated ageing and after it was over. The samples were screened with the modified glasses involved in the study.
The obtained results are listed in Table 2.
Along with the specially prepared samples, we also examined samples of museum fabrics manufactured early in the twentieth century. These latter samples were illuminated by a filament lamp and in a xenotest. The irradiation and control conditions remained the same.
When exposed to a filament lamp, samples were screened by a window glass (W), a gray mass-dyed glass, (GM), a blue mass-dyed glass, (B). In the Xenotest case, we also used a HAG-type glass. The results obtained for a wavelength of 570 nm are cited in Table 3.
An analysis of the results has revealed that the modified glasses protect fabrics against discoloration better than an ordinary window glass does, in all the cases where we observe some difference in the protective effects of glasses on fabrics illuminated by different light sources. This conclusion is valid both for old museum fabrics and for specially prepared samples.
These findings permit the conclusion that modified glasses are efficient in protecting museum fabrics.
A proper choice of glass requires that we should take account of a particular exhibit and lighting conditions, as well as the glass spectral characteristics.

Table I

Glass	Temperature the other side of screen
without glass	76.5°C
window glass	47.5°C
gray, electrochemically painted glass	38.5°C
blue, heat absorbing (Saratovskoye)	40.5°C
gray, mass-dyed glass	41°C
HAG-70	41°C

Table 2

Change in the light reflection by dyed fabrics prior to illumination and after it is over, using screens made of modified and ordinary window glasses.

Light source	Glass	Light reflection, wavelength nm
1	2	3
1. PAB sample. General discoloration of the sample, except for the wavelengths of 480 to 600 nm, where the light reflection is reduced under the Xenotest and mercury-quartz lamp illuminations.		
Xenotest		= 670 nm
	K	66%
	HAG,GM	under 68.5%
	B	
	W	76%
Filament lamp		= 670 nm
	K	66%
	HAG,GM	69%
	B	72%
	W	73%
Mercury-quartz lamp		= 520 nm
	K	23%
	HAG,GM,B	under 30%
	O	30%
LB-type luminescent lamp		No difference in the protective action of glasses has been observed.
II. PAT sample. Discoloration of the sample.		
Xenotest		= 670 nm
	K	68%
	B	80.5%
	HAG,GM	81.0%
	W	83,5%
Filament lamp		= 670 nm; = 440 nm
	K	68%; 17.5%
	HAG,GM	72%; 22.5%
	B	74%; 24.5%-26%
Mercury-quartz lamp		No difference in the protectiv actions of glasses has been observed
LB-type luminescent lamp		= 670 nm
	K	68%
	GM	68%
	B	71%
	W	72%
III. IST sample. Sample discoloration.		
Xenotest		= 670 nm
	K	23%
	HAG, B	39%
	W, GM	42%
Filament lamp Mercury-quartz lamp LB-type luminescent lamp		No difference has been observed in the protective actions of glasses has been observed.
IV. ISB sample. Sample discoloration.		
Xenotest		The light reflection is reduced in the wavelength range 490 to 620 nm. Over 620 nm, the sample is discolored. No difference in the protective actions of glasses has been observed.
Filament lamp		At wavelengths over 570 nm, the sample is discolored. No difference in the protective actions of glasses has been observed.
Mercury-quartz lamp		= 570 nm
	K	31%
	GM, B	31-38%
	O	38.5%
LB-type luminescent lamp		= 570 nm
	K	31%
	GM, B	31-35%
	O	35.5%

Notes.
(1) The value given in the "Light reflection" column of the Table are valid only for the particular wavelengths involved rather than the entire spectrum recorded with a spectro-

photometer.
(2) The following symbols are used to denote various types of glass: (a) HAG, heat-absorbing mass-dyed gray glass with an electrochemically treated surface; (b) GM, gray mass-dyed glass; (c) B, blue, mass-dyed glass; (d) W, window glass;
(3) K represents the value for a spectrum prior to ageing.

Table 3

Light souce	Glass	Light reflection wavelength = = 570 nm
Sample I (violet fabric)		
Xenotest	Control	9,5%
	HAG	35%
	GM	45%
	B, W	54.3%
Filament lamp	Control	9.5%
	GM	12%
	B	15%
	W	18.5%
Sample II. (gray fabric)		
Xenotest	Control	18.5%
	HAG, B	22%
	GM	23.5%
	W	24.5%
Filament lamp	Control	18.5%
	GM	18.5%
	B	20.5%
	W	21.5%

Note. The symbol used to denote glass types are the same as in Table 2.

PHYSICAL CHANGES OF ALKALINE-BUFFERED COTTON FABRIC

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SUMMARY

Research has been conducted to determine whether three alkaline buffers, calcium hydroxide, aqueous magnesium bicarbonate and non-aqueous methoxy magnesium methyl carbonate (Wei T'o® Solution #2) could protect cotton fabric from degradation during accelerated aging at 100°C and 100% RH in air or nitrogen. The results of chemical tests as well as experimental details including the application of buffers, the accelerated aging apparatus and chemical analyses have been reported previously (1). The purpose of this paper is to report the physical changes which occurred and to relate these results to chemical changes. All three buffers provided cotton fabric with protection against the conditions encountered during accelerated aging. The unbuffered control fabric exhibited a color change twice as great as the buffered specimens. The buffered cottons which showed the least color change also had the lowest change in carbonyl content, indicating the least oxidative damage. The unbuffered cotton lost strength at a rate of 4.5% per day; in contrast, buffered cottons showed a decrease in strength of only 1.5 to 2.1% per day. Strength loss was significantly correlated with degree of polymerization and color change. When accelerated aging took place in nitrogen, unbuffered cotton deteriorated at approximately the same rate as buffered cotton heated in air. This finding suggests that the lifetime of fragile museum cottons could be extended considerably simply by storing the textiles in an atmosphere of nitrogen rather than air.

1. INTRODUCTION

Alkaline buffers or deacidifying agents were first used on paper rather than cotton fabric. Modern papers frequently require neutralization because the paper making process leaves residual acid in the paper and the wood pulp contains impurities which accelerate the degradation of the cellulose. A number of researchers have shown that paper containing alkaline buffers is protected from deterioration during natural and accelerated aging (2-6).

Alkaline buffering of cotton fabrics is somewhat controversial at this point, in that textile conservators cannot agree that such a treatment is necessary or safe for fabrics. There appears to be good reason to consider applying an alkaline buffer in the last stage of washing some cotton or linen textiles. When cotton fabrics are washed by textile conservators, the current practice is to rinse the fabrics repeatedly with distilled water to remove all traces of detergent and leave the fabric in a neutral condition. If the cotton fabric has been oxidized during its lifetime by exposure to atmospheric oxygen, or oxidizing agents such as bleach or ozone, it will contain carboxyl groups. These functional groups on the cellulose molecule are formed when hydroxyl groups are oxidized. Repeated rinsing of cotton in distilled water protonates the accessible carboxyl groups leaving them in the free acid form and makes the fabric susceptible to further degradation if exposed to heat and moisture (7-9).

Davidson et al. (8, 9) describe the conditions under which acidic oxycelluloses can undergo auto-hydrolysis (self-hydrolysis). Perhaps an alkaline buffer or deacidifying agent could neutralize acidic degradation products and provide an alkaline reserve to combat future acidity. Cellulosic fabrics become yellow as oxidation proceeds due to the formation of new carbonyl groups (10, 11); thus, a treatment which reduces the rate of oxidation should slow down the color change. This treatment might be of benefit to unpainted linen canvas or support fabric used to line paintings as well as to selected cotton textiles.

Research has been conducted to determine whether three alkaline buffers frequently used in paper conservation could retard the degradation of cotton fabric. Buffering treatments included two aqueous agents, magnesium bicarbonate ($Mg(HCO_3)_2$), and calcium hydroxide ($Ca(OH)_2$), and one non-aqueous agent, methoxy magnesium methyl carbonate (MMMC), dispersed in methanol and fluorocarbon solvent (Wei T'o® Solution #2). Untreated cotton and buffered specimens were aged in the dark at 100°C and 100% RH in air or nitrogen over a 25-day period. The extent and nature of the degradation of cotton was determined from a number of physical and chemical tests. The results of the chemical tests as well as experimental details regarding the buffering treatments, the accelerated aging apparatus and chemical analyses have been reported in a previous paper (1).

The purpose of this paper is to describe the physical changes which took place in buffered and unbuffered cotton following accelerated aging in air and nitrogen and to relate these findings to the chemical changes which have been published.

2. EXPERIMENTAL

Experimental details regarding fabric preparation, application of alkaline buffers and the accelerated aging procedure have previously been described in detail (12). To summarize briefly, unbleached scoured cotton print cloth was treated with distilled water as a control, $Mg(HCO_3)_2$, $Ca(OH)_2$, or MMMC. The bicarbonates and hydroxide are converted rapidly to carbonates upon exposure to air. Specimens were subjected to accelerated aging at 100 ± 1°C for 25 days in the dark. A relative humidity of 100% was maintained by suspending the loosely rolled fabrics above 1 ml of water in closed Diels-Alder pressure test tubes containing either air or nitrogen. Three replications of each heating period were carried out and specimens were withdrawn at 5-day intervals.

It was necessary to use new cotton fabric for this study because a large quantity of old cotton of known history was not available. The conditions of accelerated aging were selected because they could be closely controlled and the untreated control fabric showed a significant loss of strength in a reasonable time period (25 days) when heated under these conditions. Attempts to age

fabrics at lower relative humidities were not successful.

3. TEST METHODS

3.1 Fabric Color Change

The color of specimens was determined with a General Electric Recording Spectrophotometer calibrated with a white standard, barium sulfate. The reflectance of both the outside and inside of each specimen was measured while backed with five layers of similarly aged fabric. The G.E. Recording Spectrophotometer measures tristimulus values X, Y, and Z and reflectance. Color difference, ΔE, in NBS units was calculated using the Adams-Nickerson color difference formula (13):

$$\Delta E = 40\left((0.23\,\Delta V_y)^2 + \left[\Delta(V_x - V_y)\right]^2 + \left[0.4\,\Delta(V_y - V_z)\right]^2\right)^{1/2} \qquad (1)$$

where V_x, V_y and V_z are modified Munsell X, Y, and Z values.

3.2 Fabric Tensile Strength

Specimens were conditioned at $21 \pm 2^{\circ}C$ and $65 \pm 2\%$ RH before testing. The tensile strength of the fabric was measured using the method prescribed by ASTM D1682-64 (14) but with a reduction in specimen size. Three warp strips 15x1.8 cm were cut from each specimen and raveled to contain 50 warp yarns. Tensile strength was measured on an Instron (CRE) machine using a 7.6 cm gage length, a crosshead speed of 50 mm/min and a load range of 0-20 or 0-50 lb. The time to break was approximately 10 seconds. Tensile strength measured in pounds-force was converted to newtons.

4. RESULTS AND DISCUSSION

4.1 Fabric Color Change

The average color difference of fabrics heated in air or nitrogen for periods up to 25 days are shown in Table 1. The exposure of unbuffered cotton to heat causes a gradual darkening in color from creamy white to tan. This color change is very similar to that which occurs during natural aging (15). After 5 days of heating in air and at each subsequent heating period the untreated cotton was visibly darker and was significantly different in color from the buffered specimens. Although fabrics treated with the three different buffers exhibited some darkening, they stayed considerably whiter than the unbuffered control fabric during heating. Since there was no significant difference in color among the buffered specimens following 10, 15, and 25 days of heating in air, one buffer cannot be singled out for its effectiveness in preserving the whiteness of cotton.

A plot of color change versus heating time in air (Figure 1) shows that the discoloration of the specimens increased rapidly during the first 10 days of heating. Many other researchers have reported similar results when cellulosic fabrics are heated (16-18). The levelling off and down turn of the curves is likely due to the fact that the Diels-Alder pressure test tubes had to be recapped during the last 10 days of heating and thus gaseous degradation products were able to escape from the test tubes.

Both the alkaline-buffered and control fabrics stayed remarkably white during accelerated aging in nitrogen over a period of 25 days. The unbuffered control fabric was not significantly darker in color than the buffered fabrics until after 25 days of heating. Its color change at 25 days was comparable to that of the unbuffered fabric after 10 days of heating in air.

According to many researchers, the yellowing of cotton is related to oxidative changes, particularly to the presence of C-1 aldehyde groups (10, 11). It seems logical, therefore, that the elimination of oxygen during the accelerated aging period should reduce the rate of oxidation, and hence the color change.

In a previous paper (1) the carbonyl content (aldehyde plus ketone groups), determined by sodium borohydride reduction, was reported. From the carbonyl values obtained, it was evident that buffered specimens were not oxidized as rapidly as unbuffered specimens during heating in air. The correlation coefficient (r^2) between color change in air and carbonyl content was 0.708 (15 d.f.) and was significant at the 0.01 level. The formation of a yellow or tan color in white cottons stored in air (excluding the accumulation of dirt), therefore, is a good indicator of oxidative damage. Since the rate of color change and extent of oxidation were considerably reduced when both the buffered and unbuffered cottons were aged in nitrogen, a conservator may wish to consider storing important cellulosic textiles in an atmosphere of nitrogen, whether or not the fabrics have been treated with an alkaline buffer.

4.2 Fabric Tensile Strength

The average tensile strength of specimens after each heating period and the percent strength retained (based on strength of the unaged treated fabric) are reported in Table 1. It may seem unusual that the strength of the cotton fabric increased slightly when the buffering solutions were applied; for example, the initial strength increased from $131.9 \pm 8.4N$ to $146.3 \pm 8.4N$ after immersion in the MMMC (Wei T'o ®) solution. This change was likely the result of an increase in the stiffness of the fabrics, although the stiffness lessened when the fabrics were rolled and "aged" at a high relative humidity. Peacock (18) found a similar increase in stiffness and tensile strength after spraying linen canvas with MMMC solutions. She reports that MMMC "stiffened the fabric considerably", but found that following accelerated aging most samples had the same degree of stiffness. Regarding tensile strength, she found that MMMC reduced the strength loss of linen during accelerated aging, but not as effectively as did aqueous magnesium bicarbonate.

TABLE 1 Color Change and Tensile Strength of Alkaline-Buffered Cotton Fabric Heated at 100°C, 100% RH in Air or Nitrogen[a]

Treatment	Heating Period (days)	Color Difference (NBS units)[b] Mean after heating in air	nitrogen	Tensile Strength (Newtons)[c] Mean after heating in air	nitrogen	Fraction of Treated Unaged(%) air	nitrogen
Water	0	0.00	0.00	131.9[e]	131.9[e]	100	100
	5	9.55	4.74	102.2	122.9	77	93
	10	15.96	7.36	73.0	118.5	55	90
	15	20.39	9.19	56.9	113.0	43	86
	20	24.26	11.82	41.4	103.2	31	78
	25	22.25	15.20	48.3	96.3	37	73
$Ca(OH)_2$	0	0.40[d]	0.40[d]	136.2[e]	136.2[e]	100	100
	5	5.66	5.06	119.7	129.1	88	95
	10	10.55	6.15	108.2	134.1	79	98
	15	12.88	8.11	116.3	125.1	85	92
	20	17.87	9.34	103.7	130.3	76	96
	25	15.02	10.26	108.6	128.7	80	94
$Mg(HCO_3)_2$	0	0.44[d]	0.44[d]	134.6	134.6	100	100
	5	6.16	6.53	118.6	130.9	88	97
	10	10.11	8.19	111.0	137.7	82	102
	15	10.58	10.33	121.6	135.5	90	101
	20	11.48	10.92	117.3	140.8	87	105
	25	13.26	10.69	118.1	142.2	88	106
Methoxy Magnesium Methyl Carbonate	0	0.84[d]	0.84[d]	146.3[e]	146.3[e]	100	100
	5	3.65	6.07	137.7	152.5	94	104
	10	8.34	8.33	124.8	148.0	85	101
	15	13.08	8.80	129.7	146.2	89	100
	20	15.10	10.15	131.8	151.9	90	104
	25	15.89	11.02	120.6	147.6	82	101

a Results reported on three measurements for color difference and nine measurements for tensile strength except where noted.
b 95% confidence interval based on pooled standard deviation of 1.376 NBS units (91 d.f.) equals mean ± 1.58 NBS units (n=3) and mean ± 1.37 NBS units (n=4).
c 95% confidence interval based on pooled standard deviation of 8.44 N (361 d.f.) equals mean ± 4.8 N (n=12) and mean ± 5.5 N (n=9).
d Average of four measurements.
e Average of twelve measurements.

Change in tensile strength is a convenient way to measure gross changes in fibers. Substantial degradation must occur before a change in tensile strength will be observed. It is interesting to note in Table 1, therefore, that after only 5 days of heating in air or nitrogen, the water-treated control fabric is significantly weaker than the alkaline-buffered specimens. The gap in strength retained by the unbuffered and buffered fabrics widens with time: the strength of the unbuffered fabric decreases at a rate of 4.5% per day while the buffered specimens decrease in strength about 2% per day. The difference in rate of strength loss is shown clearly in Figure 2 where a regression line has been fitted to strength data for 0, 5 and 10 days of heating. The slowest rate of strength loss is observed for the MMMC-treated specimens. At all time periods except 25 days, the MMMC-treated specimens are significantly stronger than the other specimens.

It is clear from the tensile strength data in Table 1 that the degradation of unbuffered cotton during moist heating in nitrogen occurs at a slower rate in this non-oxidative atmosphere than in air. The fact that the strength loss is caused by hydrolysis of molecular chains was confirmed by cellulose viscosity measurements and degree of polymerization (DP) values which were reported previously (1). After 20 days of heating in nitrogen the DP of unbuffered cotton was 43 ± 10% of the unaged value.

The strength of the fabrics treated with $Mg(HCO_3)_2$ and MMMC did not decrease during 25 days of heating in nitrogen. Fabric treated with $Ca(OH)_2$ showed a slight decrease in strength but was significantly stronger than the water-treated control, having a strength equivalent to 94% of the unheated $Ca(OH)_2$-treated fabric after a 25 day period.

Tensile strength (expressed as a percent of the original buffered or unbuffered cotton) was found to be significantly correlated with color change in air (r^2 = 0.996) and in nitrogen (r^2 = 0.898). In these experiments, therefore, change in color was a good indicator of loss in strength. A significant correlation was also found between tensile strength and DP (r^2 = 0.777), as expected, because the shortening of molecular chains causes a loss in tensile strength.

The comparison of these findings with the work of other researchers is difficult because most research on deacidifying agents has been done on paper. Block (19), however, has treated cotton specimens with $Ca(OH)_2$ solutions. After 7 days of dry heat at 150°C, he found that water-treated fabric retained approximately 2% of its original strength while the $Ca(OH)_2$-treated fabric

retained about 9% strength. Peacock (18) treated linen fabric with the same Wei T'o® Solution #2 (MMMC) used in this study and aqueous $Mg(HCO_3)_2$. Accelerated aging was carried out at 50% RH and 70°C for 21 days. Both buffering agents reduced the rate at which linen lost strength, the aqueous $Mg(HCO_3)_2$ being more effective than the MMMC solution.

5. CONCLUSIONS

There is no doubt that when cotton fabrics are treated with the alkaline buffers $Ca(OH)_2$, $Mg(HCO_3)_2$ or MMMC and subjected to accelerated aging at 100°C and 100% RH, they deteriorate at a slower rate than when unbuffered. All physical tests reported here and chemical tests reported previously (1) support these findings. For example, buffered cotton which was heated showed less color change, retained a higher tensile strength, a higher degree of polymerization and possessed a lower degree of oxidation than unbuffered cotton.

Although all buffers performed well, and could be useful in the deacidification of cotton textiles, the non-aqueous MMMC treatment was particularly effective. A real advantage to the conservator of textiles is the fact that both $Mg(HCO_3)_2$ and MMMC offer protection to cotton yet one is applied from an aqueous solution and the other, from a fluorocarbon/methanol solvent. The nature of the textile to be treated, including such factors as dyes and finishes which are present, will dictate which might be used.

How does an alkaline buffer affect the degradation of cotton cellulose? From the research findings reported here and previously (1), it can be concluded that alkaline buffers function in several ways. If sufficient moisture is present to swell the cotton and mobilize the buffering agents, they appear to be able to enter accessible regions and neutralize protons from ionized carboxyl groups or neutralize acids from external sources. In addition, they have been shown in this study to reduce significantly the rate of oxidation of cellulose. Other researchers have demonstrated that alkaline buffers protect the physical properties of cellulose (2-6, 17-19), but no one else has reported a reduction in the extent of oxidation.

It is interesting that unbuffered cotton subjected to accelerated aging in an atmosphere of nitrogen degraded at a rate very close to that of buffered cotton heated in air. This is evidence that cotton fabrics can be preserved without treatment with an alkaline buffer if they can be stored in nitrogen or a nonoxidative environment.

Conservators of textiles are very cautious about adopting new procedures or treatments for textiles. Even though there is considerable laboratory evidence that alkaline buffers protect cotton during accelerated aging, some questions posed by conservators still require attention and are currently under investigation.

ACKNOWLEDGEMENT

This investigation was supported at North Carolina State University in part by the National Museum Act, which is administered by the Smithsonian Institution. The authors are grateful for this assistance.

SUPPLIERS

Wei T'o Solution®#2, Wei T'o Associates
P.O. Drawer 40, 21750 Main Street
Matteson, IL 60443, U.S.A.
Diels-Alder pressure test tubes, Ace Glass Inc.
Box 688, Vineland, NJ 08360, U.S.A.

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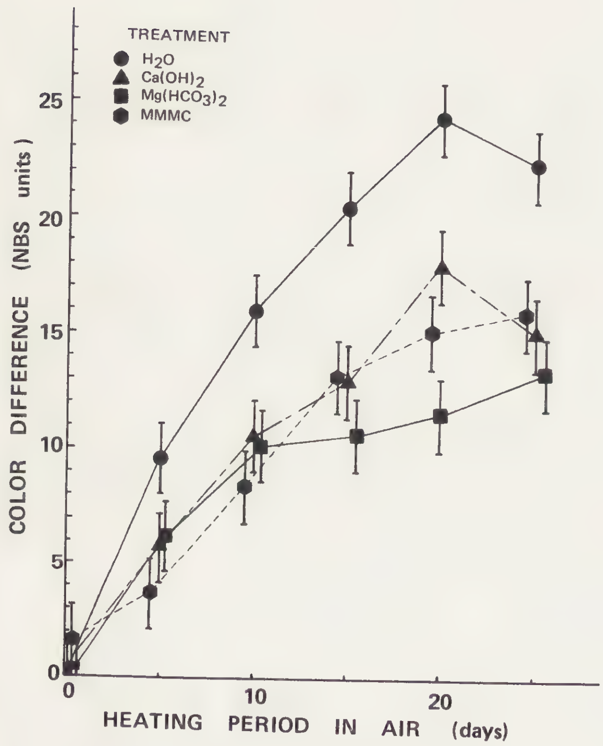

Fig.1 Color change as a function of time for alkaline-buffered cotton heated at 100°C, 100% RH in air. Confidence intervals are as defined in Table 1, footnote b.

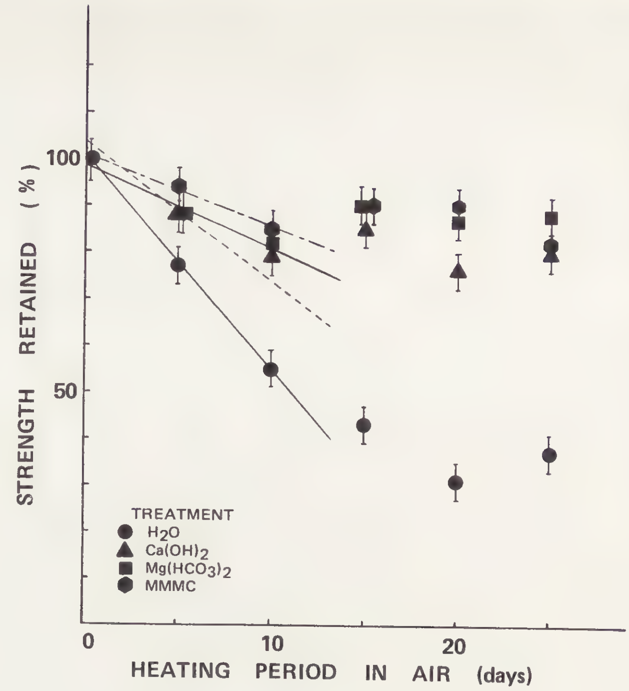

Fig.2 Tensile strength as a function of time for alkaline-buffered cotton heated at 100°C, 100% RH in air. Confidence intervals are as defined in Table 1, footnote c.

THE RESTORATION OF PRINCE FERENC RÁKÓCZI'S BANNER

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SUMMARY

The banner to be reported on has remanied to us from the war of independence led by the Hungarian Prince Ferenc Rákóczi /17o3-1711/ and was one of his personal colours. In accordance with afreement signed in 1926 in Baden, it was brought back to Hungary and has been in the possession of the Hungarian National ever since.

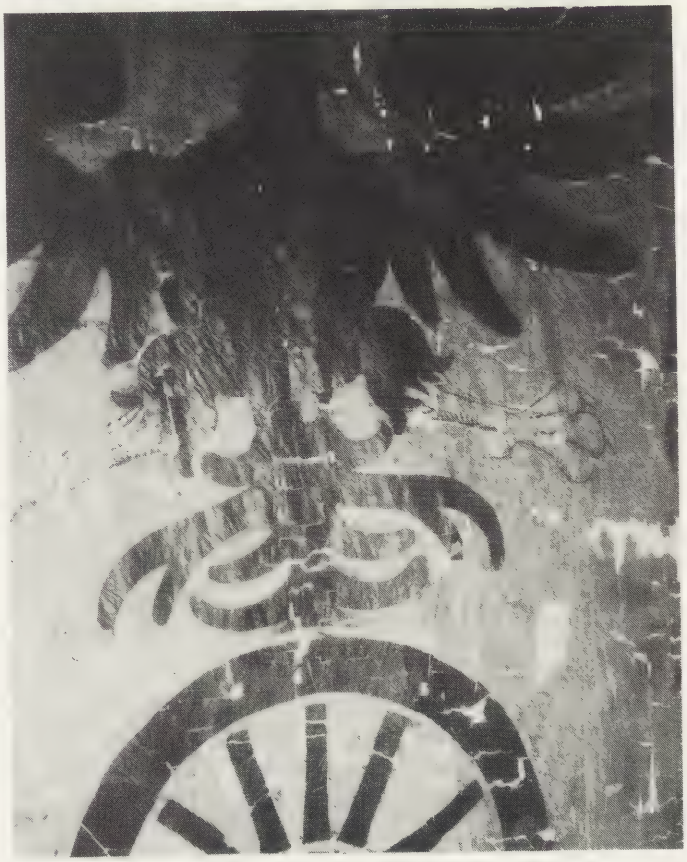
The banner is of light blue colour, its silk material is faded. On both its sides the coat-of-arms of the Rákóczy family with the initials of the prince above them are to be seen. The size is: 28o x 27o cm.

Earlier the banner was sewen in between tulle in order to consolidate it. This 'consolidation' brought about a great many difficulties since the silk that had already been brittle further deteriorated, tore and turned dust. The part painted in oil made the case more complicated. Owing to its historical importance and deteriorated state the conservation and restoration process to be elaborated was meant to save this valuable item from further decay. Drawing a lesson from the earlier experiences of similar restorations, sewing as a means had to be discarded. Therefore we had to experiment with doubling and sticking. The sticking of the painted section took place by Paraloid B72 /an acrylic substance/. The already 'unified' picture was then lined by silk organdie that was previously treated with Mowilith. The lacunae in the painting were completed by some priming composition and retouched. Owing to the huge size of the banner as well as the considerable losses in the tightly woven silk, the banner had to be consolidated by a similar, heavily wefted silk support.

Banners have always played an important role in the course of history, as alongside the moral aspect there have been practical considerations, too. The banner indicated the position of the leader, directed the situation of the different fighting units, it was held in high esteem and protected in danger. The coat-of-arms, inscriptions and slogans on it as well as its colour reflected a given national status and revealed the social conditions of a certain epoch.
Only few banners have survived from the War of Independence /17o3-1711/ led by Hungarian Prince Ferenc Rákóczi II and the ones that remained were carried off to Vienna as spoils of war. The above banner - one of the main colours of the Prince - was captured in the battle of Trencsén /17o8/. /1/

In 1919 a forceful movement as well as a lengthy series of negotiations started with the aim of recovering such Hungarian arts treasures from Vienna. In 1926 the agreement on returning military state property of Hungarian origin and relevance was concluded in Baden. In compliance with the above document some 2oo banners arrived home, among others the above-mentioned Rákóczi banner which is in the possession of the Hungarian National Museum at present. /2/

In 1933 the Hungarian National Museum arranged an exhibition from the collection of the returned art treasures. According to the 35th article of the catalogue published on this occasion it was made of faded, light-blue silk with the Rákóczis'heraldic figure on both its sides. /3/ The coat-of-arms of the Rákóczi family was dominated by a spread-winged black eagle with a golden crown on its head holding a sabre with gold hilt and standing on a gold wheel evolving from a triple mountain. /4/ Above the coat-of-arms the initials of the Prince are to be found; F/ranciscus/ R/ákóczi/. de F/első/. V/adász/. C/onfoederetorium/. R/egni/. H/ungarae/. S/tatuum/. D/ux/. et T/ranssilvaniae/. P/rinceps/. /5/ The size of the banner is 28o x 27o mm.



The banner was sewen in between tulle. Parts of the heraldic figures.

Possibly for the purposes of presentability in 1933 the banner was sewn in between tulle that was meant to support the weak silk fabric. This 'consolidation' brought about a number of difficulties later on. The already brittle silk further deteriorated, it tore and broke along the sewing stitches, and the condition of the object was aggravated by the oil paintwork, too. The painting was applied directly onto the tightly woven silk, in oil, without any priming. The paint came through the fine fabric and therefore the design was repeated on the other side. Thus the heraldic figure as well as the letters were repeated as if reflected in a mirror. As a result, there was a double paintload to be found on the painted surface. The ageing of the textile accelerated here, and soon cracks and flaking appeared. This seems to be proven by the presence of tears held together by some coarse thread, a mending of probably earlier origin than the consolidation by tulle.

Owing to its historical importance as well as the badly deterorated state of the item it was inevitable to find a consolidation and restoration method that would hopefully save this valuable object from further losses. The procedure was expected to put it into a harmless state that would prevent further decay and make it suitable for presentation for the general public.

The basically different condition of the painted and unpainted parts of the banner called for a selective treatment on behalf of the restorer. While the unpainted part flowed gently, the paintwork was somewhat stiff, and the change in the dimensions of the two parts were uneven. The ageing of the whole of the banner made this difference in dimensions even greater and more conspicuous. The really weak condition of the banner became visible only after it had been detached from the tulle. First it was possible to remove the tulle from the face of the banner only.

The paintwork was soiled, crumbled and hard with a thick layer of dust on it just as in the case of the unpainted surface. The traces of dust having deposited because of the tulle were also easily detached. In order to clean it, it was necessary to remove the tulle support from the other side, too. At this point the procedura was continued by material tests. The determination of the fibres was carried out by the usual chemical reactions. Both the weft and the warp were made of silk corssband /S-twist/. Density: warp 51, weft 66. The examination of the dyestuffs was also seemed necessary since according to the old catalogue as well as the descriptions of art history there had been no mention made of a major principal banner of greenish shade. /6/ Some of the paints of the paintwork were also identified.

Prior to the cleaning of the banner the paintwork had to be softened and stabilized. For softening lauril-alcohol was used as a result of which the paintwork became soft and flexible. /7/

After carrying out the colour fastness tests it was decided that watery treatment was possible. /8/ The next step was the joining of the crumbled paintwork which was done by a synthetic resin, Paraloid B72. /9/ The extremely poor condition of the banner made it necessary to mount it for which purpose sewing conservation was rejected drawing the lessons from previous restorations. Having got acquainted with the experiments going on in the Amsterdam Central Laboratory, where doubling by sticking is one of the usual methods, I decided to do the same by applying Mowilith. /1o/ Silk organdie of matching colour was treated by a 1:1:6 mixture of Mowilith DMC2, DM5 and distilled water. The banner was laid on this film and ironed onto it. /11/

The banner was detached from the tulle. Parts of the heraldic figures.

The lacunae in the paintwork were completed by a priming paste and retouched afterwards. /12/ Owing to its huge size the banner had to be reinforced by another piece of tightly woven silk fabric thus making it possible for us to exhibit the object.

The restored banner before retouched. Part of the heraldic figures.

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12 cf. Ref. 8

CONTRIBUTION TO THE STUDY OF THE CONSERVATION OF MONUMENTAL TAPESTRIES

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SUMMARY

We review the problems which are encountered in the conservation of large tapestries and the solution we propose for the selection of the materials (warps and weft threads, dyes, cleaning products,linings) and for the conservation processes (cleaning, strengthening).

1. INTRODUCTION

Large tapestries are distinguishable from other textiles by specific problems : Their weight, each m^2 of an old tapestry weighs about 1 kg. This weight hangs mainly on the wefts because the warps are horizontal. This is particularly damaging for silks wefts; Their dimensions, which makes it necessary to have large workshops and appropriate looms. Moreover the duration and the cost of the treatment is proportional to the number of threads per cm and to the area of the tapestry; The previous restorations, for a long time tapestries were considered as furniture which could be cut out and mended without much caution. At the beginning of the 20th century, the use of bad dyestuffs created two new difficulties. The fading of these dyes badly disrupts the harmony of the shades and their poor fastness to washing henceforth prohibits cleaning with water. On the other hand, the replacement of woolen warps by cotton ones often promoted deformation.

These three characteristics must be born in mind throughout the different steps of the treatment : documentation, cleaning, strengthening and lining (1).

2. SELECTION OF THE MATERIALS

2. 1. Warp threads

We lay down as a principle that it is always safer to use conservation materials which are as similar as possible to the original ones but a little less strong. Thus broken or missing woollen warps are replaced by woollen threads and cotton ones by cotton threads. Indeed when cotton warps are attached to a woolen one some strain and tear may occur because of the different properties of the fibers such as the regain, the breaking strength, the extension at break, etc ... In these cases the old fiber is always the victim.

Therefore we select warps which have almost the same twist as the original ones but which are a little thinner. In this way they are not stronger than the old warps and we minimize the thickness on reweaving.

2. 2. Weft threads

2. 2.1. The fibres

We follow the same principles as for the warp threads but here silk gives rise to additional problems. Natural silk becomes every day more difficult to find in the various qualities which were used in ancient tapestries. We now get our supplies from Japan and China (2). As a general rule the new silk wefts must be thinner than the free silk threads on the back of the textile. Indeed the woven silk threads have been stretched and thinned by hanging.

On the other hand, the breaking strength of silk dramatically decreases on long term stretching. In a good deal of tapestries which represent a landscape, the sky in the upper part mainly consists of silk wefts. The last ones have to resist the weight of almost the whole tapestry hanging under them. The use of silk threads for mending these parts is thus questionable. With regard to the appearance the replacement of silk by silk is the most satisfying choice but the durability of this operation is precarious. Unfortunately all other fibers present more disadvantages. Wool does not have the appropriate shine, mercerised cotton may shrink in further washings, polyester is too strong and does not react at all with variations of the relative humidity unlike the woollen warps which it must cover.

In our museums,we may hope to garantee reasonable conservation of the silk threads providing that the tapestry is properly lined and should not hang for longer than 6 months at a time, that the ligthing does not exceed 50 lux without ultraviolet ligth and that finishing products and dyes for the silk have been selected to this end.

2. 2.2. The dyes

Dyeing silk and wool must in no way injure the fibres not only immediately but also in the long term. This leads us to prefer milling premetallised acid dyes. They are applied from a weak acid bath (diluted acetic acid) very near the isoelectric pH of the fibres and they are very fast to washing because of strong Van der Waals attractions with the fibres (3). Light fastness is insured by the use of metal-complex or premetallised acid dyes. These are mordant dyes which have the metal incorporated in their structure. They give fastness properties similar to those of the true mordant dyes but they don't require separate mordanting process. We use only the dyes of fastness B.S.6 or more. Silk dyeing is performed under 75°C, with as little handling and stirring as possible and as short a time as possible. Matching of the required hues is obtained by a suitable mixture of the three "secondary colours"(cyan,magenta, yellow). This trichromy was worked in the past with three natural dyes : indigo (Isatis tinctoria), madder (Rubia tinctorum) and weld (Reseda luteola). In this way it is possible to restrict the number of different dyes to be used. Our usual dyes are f.i. the blue C.I. Acid Blue 296, the red C.I. Acid Red 217 and the yellow C.I. Acid Yellow 111. Paler shades of any colours are made by using smaller quantities of dyes. Duller colours are produced by changing the ratios of the component secondaries since the three ones together make black. The mixtures of the selected dyes have been submitted to the Xenotest in order to detect any damaging interactions.

2. 3. Cleaning products

2. 3.1. Solvents

When possible washing with water is always the most favourable procedure. Water enables the elimination of a lot of different types of soiling and furthermore it permits the removing of a good deal of the permanent deformations (4). Unfortunately water is sometimes forbidden. This is the case f.i. when the tapestry contains cotton threads sensitive to crimp, when the fibres are too strongly damaged or when some dyes bleed from the fibres on wetting or diffuse on drying.

When drycleaning cannot be avoided we select white spirit because chlorine solvents can sometimes contain traces of hydrochloric acid. In Belgium, we have been looking for a long time for drycleaning firms which will agree to work according to our requirements : the solvent must be freshly distilled, the textile may not be rubbed, only very little nonionic detergent may be used and it must be thoroughly rinsed out.

2. 3.2. Additives

Foreign substances are always better not introduced into art objects. Therefore we assist water cleaning only with a nonionic detergent in very low concentration (0.01-0.02 g/l). Tap-water may be used for the first baths because this kind of surfactant does not precipitate the Ca^{++}ions. Last rinsing is carried out with demineralised water. In this way polyphosphates are not needed. These substances could react with the metallic mordants of the old dyes (5).

2. 4. Linings

2. 4.1. The fabric

The lining not only acts as a barrier against soiling but its main role consists in sustaining the weight of the tapestry. The fabric has therefore to possess a high breaking strength and a low extension at break. Indeed after a while, the lining should not hang from the tapestry instead of the contrary. Therefore thin linen fabric (200g/m^2) has been selected in order to minimize its weight. It is boiled before use to eliminate the finishing products and to relaxe the deformations which could promote further crimp. Some people prefer using cotton instead of linen because bast fibers are more moisture conductive. Providing that the tapestry hangs at a little distance from the wall this seems less important to us than the mechanical properties.

2. 4.2. The dyes

Linen linings need sometimes to be dyed when they are cut in pieces to reinforce large holes. We select a special range of direct dyes of excellent fastness to light, C.I. Direct Black 118, C.I. Direct Red 207, C.I. Direct Disch.Orange 107. For dark hues the fastness to washing is to be improved by an aftertreatment with a cationic fixing agent.

3. SELECTION OF THE PROCESSES

3. 1. Cleaning with water

Preliminary tests must prove the resistance of the fibres and of the dyes. Surface soiling is first removed with a vacuum cleaner. The tapestry is then laid down flat in a bath which is built to its measurements with a polyethylene sheet and four beams. Soiling is pressed out with flat sponges or with paint-rollers avoiding any rubbing. It is advisable

to leave the textile wet for as short a time as possible. Dyes on silk could bleed out because the high cristallinity of this fibre hinders the penetration of the dyes.

This process is fully satisfactory even for heavily soiled tapestries. One or maximum two cleaning baths with nonionic detergent (0.01-0.02g/l) are needed. Three or four rinsing baths then follow till a negative test is obtained for the presence of detergent (6). During these operations the textile is turned over several times by rolling it around a long roller covered with a polyethylene sheet and perpendicularly to the warps direction. Excess of water is eliminated with blotting paper and towelling. Finally warps and wefts are replaced on their proper positions with the help of little rubber rollers which are moved from the center of the tapestry toward the edges. Small lead-blocks maintain these positions during the drying.

3. 2. Strengthening

The consolidation of tapestries is an awkward problem which is still debated in most workshops. Let us briefly discuss the most usual methods we have carried out.

3. 2.1. Full restoration

The tapestry is stretched out again on a loom and all missing warps and wefts are rewoven. This should be done with great care to preserve the original threads and a close respect of the original techniques.

Aesthetically, this method is very attractive because the tapestry fully recovers its homogeinity (Fig.1, 2). Nevertheless this could give a false illusion for the spectators and it changes the ancient appearance of the textile. A detailed documentation of the restorations is therefore highly necessary.

The strength of the textile is optimum providing that the proper materials have been used and that the new threads have been anchored in sound areas. Even the wefts which were not replaced are reinforced by being pressed together.

Cost is unfortunately very high because of the duration of the work. For a tapestry showing 6 to 7 warps/cm, we estimate that the work needs about 1300 hours/m^2. This can only be carried out by workshops which are subsidized f.i. by the State because it could not be paid. Many private bussinesses shorten the work by eliminating all degraded threads and reweaving large areas with a simplified technique. This is of course very objectionable.

A important problem still remains : the problem of large missing parts. Some people solve it by reweaving large plain areas or by copying ancient cartoons when they still exist. In this case we prefer the relining method (see beneath 3. 2.2).

Fig. 1, 2 :"Paulus and Elymas." Brussels tapestry, 16th Century. Byloke Museum, Ghent, Belgium. Full restoration - before (fig.1) and after (fig.2) treatment.

3. 2.2. Patchwork consolidation

We consolidate holes and damaged areas by sewing pieces of dyed linen fabric with the "laid and couching" technique (7). The laid silk threads are anchored in sound areas, perpendicularly to the warps .

Fig. 3 : "Patchwork consolidation" : "laid and couching" technique.

Aesthetically, the tapestry has an "archaeological" look. The woven texture is disrupted by linen fabrics. The naked warps appear in several places. This is particularly perturbing in dark areas.

The strength is fairly good providing that a full relining has been sewed onto the upper third of the tapestry which carries the most weight, that the "laid and couching" stitches are extended at least 10 to 15 cm into the sound areas and that the alternate rows of stitches overlap along at least 2/3 of their length. Nevertheless, damaged threads still remain in danger.

Cost is reasonable. A tapestry with 6-7 warps/cm needs about 100 hours/m^2.

Unsolved problems are the mechanical effect of the linen pieces on the hanging tapestry and also the behaviour of these patches on further washings.

3. 2.3. Intermediate technique

Several workshops have tried to bring together the advantages of both previous methods. They usually sew a lining (patches or complete). The damaged parts are fixed upon it by sewing new wefts but less close to each other than in the original weaving (8).

Aesthetically, at a distance, the aspect is less "archaeological" but here again another texture disrupts the homogeinity of the textile.

The strength can be compared with the results of method 3. 2.2.

Cost is also intermediate between costs of methods 3. 2.1. and 3. 2.2.

The problem are the same as for method 3. 2.2.

3. 3. Final lining

M. Ordony has studied the influence of linings on large hanging textiles. She showed that the best method of sewing consists in alternate vertical stitches. We apply this method but the stitches are sewed closer to each other on the upper third of the tapestry. The stitches are carried out by several couples of restorers placed on both sides of the tapestry which is suspended with its lining from a broad band of Velcro.

4. CONCLUSION

Full restoration may be carried out only for exceptional cases. Preference must be given to the conservation by fixing. Some little areas may sometimes be fully rewoven when the drawing still remains and for reinforcement. Each tapestry has its own problems and needs different compromises. In any case a detailed preliminary study is indispensable. All treatment must be foreseen, justified and marked on a photograph before carried out.

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EVALUATION OF MOUNTING TECHNIQUES USED ON VERTICALLY HUNG TEXTILES

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Summary

The evaluation of stress on textiles displayed or stored in a vertical position uses warp and weft yarn displacement in balanced weave fabric cut on the true bias as a measuring tool.[1] The effect of gravitational pull on textiles hung with various backing fabrics, supports, and stitching pattern as well as constriction of weave due to stitch type and/or placement is measured.

The research involves 1) an informal survey of techniques used in American museums for hanging textiles, 2) an elimination study to choose optimal techniques of preparing textiles for hanging which will be more thoroughly analyzed, 3) a main study to evaluate the stress of different methods of hanging and various patterns of stitching textiles to a backing using the backing fabric and type of stitch determined to be optimal in step 2.

The elimination study indicated running stitches attaching a textile to a balanced, plain weave fabric with medium to high thread count were the safest choices for preparing a textile to hang vertically. The analysis of the main study which is scheduled for Spring 1984 will help conservators, curators, and display staff as well as private collectors make better informed choices in planning for textile exhibition.

Introduction

Too often the techiques used in supporting a historic or valuable textile on exhibition detract from or mar the beauty of the piece as well as cause physical damage. The condition of a textile that has been hanging for a period of time is one indication of the safety and effectiveness of support methods and materials chosen, but a valid evaluation of the support system requires records of the prior condition of the textile plus techniques and materials used. This kind of evaluation has been the basis for judging support systems in the past; however, the procedure makes comparison of systems and components difficult.

The researcher has been concerned with the best choices from a wide diversity of methods used on vertically hung textiles especially when she teaches textile conservation classes or consults with museum personnel and private collectors. "Methods of Mounting Flat Textiles" was the theme for the Sixth Annual Symposium of the Harpers Ferry Regional Textile Group in September 1982 and was the impetus for this research. That people needed to know more than a survey of methods and materials used became obvious in the initial preparations of a paper for the symposium.

- What properties are needed in a good backing fabric?
- Which method of supporting a textile creates the least strain and distributes the strain as evenly as possible over the entire textile?
- Which stitches are best to use in attaching backings?
- What arrangement of stitches best attaches a backing to a valuable fabric?
- Which combinations of techniques and materials offer the best support for vertically hung textiles?
- How can strain resulting from vertical exhibition be measured?

The authors felt that they could design experiments to answer the first five questions if the problem posed in the last question has a solution. Research on a similar problem earlier provided the theoretical basis for tests on flat fabric hung vertically.

Theoretical Basis for Tests

In 1977 while curator of the College of Home Economics Historic Textiles and Clothing Collection at Kansas State University, the researcher began improving the collection storage. Much more vertical than horizontal space was available for garment storage, but the choice of hangers was difficult since the best type of hangers was an untested factor. The literature contained various recommendations, mostly based on the test of time. Furthermore, no information was available on where the strain of hanging was greatest.

The researcher developed a technique to test various hangers for the support they could provide bodices hung vertically. A chain placed in a casing at the waistline of sample bodices would accelerate the pull of gravity and simulate the weight of a heavy skirt. The test for strain was based on the bodice front and back pieces being cut on the true bias of a balanced weave, yarn-dyed gingham. The normal 90° angle orientation of warp and weft yarns would change as the bias-cut fabric was pulled or stressed by gravity. By measuring the amount of distortion from the 90° angle at specific sites, a pattern of strain would be evident. Measurement would be easy with the colored gingham squares.

Vicky Kruckeberg, now the textile conservator at Peebles Island for the New York State Park Service and then on the Kansas State faculty, was awarded a grant to conduct an experiment using the bias-cut gingham test for stress.[2] Measurement of the weave distortion successfully showed the amount of stress in various sections of weighted bodices on padded and unpadded hangers as well as three-dimensional forms. After statistical analysis of the stress measurements, hanger selection for collection storage was made with more assurance.

In 1982 when faced with the need to know more about strain on textiles exhibited or stored on a vertical plane, the researcher revised the previously used method for application to free-hanging flat textiles. A balanced weave, yarn-dyed 1/4 inch (6.35 mm) gingham fabric cut on the true bias would be used to detect strain. The experimental model would be composed of a backing fabric stitched to the bias-cut fabric instead of a historic textile. A metal bar enclosed in a casing sewn at the lower edge of the fabrics to be tested would accelerate the pull of gravity. This method of weighting the samples eliminates testing framed textiles or those attached to a stretcher, although some of the findings are applicable to those support systems.

First Step - An Elimination Study

An informal survey of conservators in over a dozen states revealed a wide variety of backing fabrics, methods of hanging textiles, types of stitches, and arrangements of stitches used in preparing textiles to hang vertically. Since an evaluation of all of these factors with a replication could require testing almost 2,000 samples, a two-step investigation was chosen. An elimination study would provide the means for selecting treatments to be part of a main study. The objective rationale for such a selection would be based on a statistical comparison of methods or materials as well as a visual inspection of the textiles under stress.

Procedure

Based on the survey information, treatments tested fall into the following categories:

A. Backing fabrics
   1. None
   2. Net
   3. Flannel
   4. Gingham

B. Methods of hanging
   1. Three rings
   2. Slat in casing
   3. Velcro
   4. Dowel in casing
   5. Dowel in casing at 5° angle

C. Stitching patterns
   1. Vertical rows
   2. Outlining a design
   3. Around the perimeter
   4. Union Jack
   5. Crossed diagonals
   6. Horizontal rows
   7. Ordered short rows
   8. Random short rows

D. Type of stitches
   1. Running stitch
   2. Four running and one half-backstitch
   3. Half-backstitch
   4. Catchstitch

The three backing fabrics in part A were used most often by conservators although some textiles are hung with no support. Net was reported in the survey with surprising frequency as a backing fabric even for textiles to be displayed vertically. Flannel was chosen often because a napped fabric is supposed to provide more frictional support for a historic textile. Muslin, percale, and other medium to high thread count plain weave fabrics were used most commonly. To represent this last group of backing fabrics, gingham was selected because the grainline was easy to see in both lengthwise and crosswise directions, and cutting exactly along a thread was quite easy. Cutting and sewing had to be thread perfect not to influence test results.

The three backing fabrics were tested with bias-cut gingham attached to them to measure how much support they would provide under stress. One bias-cut gingham sample had no backing. The arrangement of stitches on the three samples with backings had to be the same, and horizontal rows were selected since the researcher knew horizontal stitching helped distribute the gravitational stress evenly across a textile. The stitch type chosen was a combination of four running stitches and one half-backstitch sequence. This type was chosen because of the stability it offers.

The final part of the design for testing backing fabrics involved the method of hanging the weighted test samples. Again a method was selected on the grounds of experience since part B had not been done yet. A casing sewn at the top of the fabrics to support a round rod was chosen because of the evenness in the distribution of strain that would be offered.

Part B of the elimination study was designed to test various methods of hanging textiles. The six methods chosen represent the most frequent ones used in the museums surveyed. The rings were used to approximate the same stress as nailing, stapeling, or pinning a textile onto a support-techniques that produce acute stress in just a few places. One sample was tested with the support and weighting rods against a solid surface that was tilted at a 5° angle to see if a slight variance off the vertical plane would help minimize the pull of gravity. Three woven tapes sewn on either side of the tapes were placed vertically in the center and middle of each half. No support backing was used on these samples so that more extensive distortion could be seen in the bias fabric. For this reason the samples hung only 12 hours instead of the 24 hours for part A and C.

The arrangement of stitches to hold a backing to a textile was the third factor studied, in part C. These samples were supported by a rod in a casing as for part A. The backing fabric on all samples was 1/16 inch (1.59 mm) gingham cut on the straight grain. The type of stitch chosen was again the same as part A - a combination of four running stitches and one half-backstitch sequence. Unfortunately this would be a poor choice in the design, but part D had not been done yet. The length of the hand stitches measured approximately 1/2 in. (1.27 cm), and the squares in the gingham helped assure constancy of stitch length and proper placement of stitches.

In part D three different stitches were tested along with a combination of two of them. The testing of stitches differed from the previous tests in that the effect on an entire sample was not observed. Only weave distortion along the line of stitching was considered. When distortion did occur, it was observed and photographed but not measured because yarn displacement was so severe. The cotton thread was stayed with two close stitches at the ends of the rows; no knots were used. The stitches were placed in horizontal, diagonal, and vertical orientations.

The test samples measured 25 x 14 inches (73.5 x 35.6 cm), giving a finished 21 x 14 in. size which is a 3 to 2 length to width ratio. The bias pieces were cut on the true bias of 1/4 in. (6.35 mm) yarn-dyed gingham made of 65% polyester and 35% cotton. Pairings of bias-cut pieces to backing fabrics and treatments was by random assignment.

Other than samples B1 and B3 - rings and velcro supports, all samples had a casing sewn at the top to hold a 1/2 in. (1.27 cm) wood support rod or for B2, a flat slat. The tubular casing was sewn at the top and bottom with machine stitching which had more even spacing and tension than hand stitches. The sewers took extreme care to align the horizontal rows of stitches with the weft yarns of the backing fabrics and the true bias of the gingham.

All samples had a casing at the bottom to hold the weighting rod. These casings were made by turning up and machine stitching a hem of the fabric rather than attaching a separate casing so the gravitational pull would continue stressing the yarns of the test fabrics. Threaded steel rods provided the weight to accelerate the pull of gravity. The masses of the rods were equalized to the nearest thousandth of a gram by winding small wires in the grooves of the rods. Each 469.544 g (16.434 oz) rod rested on a curved piece of cardboard to prevent individual yarns being stressed by the thread rods and to lessen the chance of disorienting the position of yarns in the weave during insertion of the rods.

The distortion of the weave after stress was determined by measuring the amount of displacement of the usual 90° warp and weft orientation. The difference in the length of three gingham diamonds (squares turned sideways due to bias-cut), measured before the weighting bar was inserted and after an allotted amount of time, was defined to be the distortion in the weave due to the effect of gravity. Measurements were taken at 24 points selected from 24 equal partitions of the area bounded by the machine stitching at the top and bottom and by the cut edges on the sides. A stencil standardized the marking of each bias gingham surface so all samples were measured in the same places. The researcher made all the measurements herself to minimize measurement error, and she staggered the start times so that final measurements would be made after the same length of time for all samples. All the fabrics and equipment were preconditioned, and testing occurred in a conditioning room at standard conditions. The use of a leveling instrument assured that the support bar for each sample was perpendicular to the pull of gravity throughout the test.

The researcher took notes on the physical appearance of the samples several times during the testing period. Photographs of the samples were made as each part of the test was completed. Samples were photogrpahed under standardized AATCC lighting and viewing arrangements and also in a raking light with samples hung vertically.[3]

Results and Conclusions

Both the measures of distortion and the physical appearance of samples under stress helped evaluate the treatments. In the tests of backing fabrics, net was not significantly different statistically from no back at all. Net offered no support to help the fabric attached to it withstand the pull of gravity. The width of the sample decreased as the length increased producing from 1 to 4.5 mm distortion in the weave of the bias-cut gingham at every point measured. Conservators should not depend on net to relieve gravitational pull on a textile.

No significant difference was found in the support supplied by flannel and gingham. Both fabrics supported the bias-cut gingham well with at least a third of the measured positions showing no distortion and the maximum distortion at a measured point being only 1.5 mm. The fact that flannel has a lower thread count and weaker yarns than other popular backing fabrics did not prove to be significant. The napped finish did not give much additional support because about 15 vertical wrinkles in the flannel formed long narrow tubes where the backing did not touch the obverse fabric at all. This phenomenon also occurred with the gingham backing and deserves further study.

Since flannel and gingham were determined not to differ significantly and offered good support, backing fabrics will not be a variable in the main study but will be held constant throughout the study. Gingham will be used again because the yarn-dyed lines lessen the possibility of stitching off grain and affecting test results.

The tests comparing methods of supporting a fabric hung vertically indicated statistically significant differences exist among the techniques used most often. The three-ring support was the worst among the methods tested; in fact, the distortions were the greatest in the entire elimination study. The four techniques (B2, B3, B4, B5) that provided uniform support across the entire width of the test samples were observed not to differ significantly. The physical appearance of the four was similar, also.

The three ring support need not be included in the final study. A dowel in a casing will represent the three techniques that tested so similarly - velcro, slat in casing, and dowel in casing. The support at a 5^{o} angle (B5) also will be included for further testing. Although not significantly differenct from the other three, the measured deformation was less than the other three samples which hung vertically.

Some conservators use woven tapes sewn vertically to the back of a textile, sometimes hanging a textile by the tapes, but more often tapes were used in conjunction with some type of upper, uniform support. A bias-cut sample with tapes sewn on the back experienced strain that was comparable to the flannel or gingham backings, but taped supports could not be analyzed validly with backing or with hanging since part A and B had all factors held constant except for one variable. Taped supports will not be part of the main study, either. Visual inspection of the support provided by tapes revealed diagonal wrinkles on the obverse fabric due to uneven support.

The pattern of stitches that allowed the greatest stress is quite possibly the most frequently used arrangement by conservators - vertical rows. This technique was significantly different from all the others and allowed distortion in all places except one center top spot. The displacement was fairly evenly distributed and not more than 1 mm at every point measured. The vertical wrinkles in the backing fabric that limit contact with the obverse fabric are quite evident with the vertical stitching pattern. This result indicates vertical stitching would be the poorest choice of those tested, but because of its popularity, the technique will be included in the final study.

The rest of the stitching patterns were quite similar in the measurement of strain - all producing little or no distortion. The list of treatments at the beginning of the procedure section ranks the patterns in order of stress measured with C7 and C8 showing almost no distortion. A longer test period in the main study may produce more measurable distortion. Differences were noted, however, in the physical appearance. Both the crossed diagonal and union jack arrangements produced little puffs in every section of the bias-cut gingham. Some wrinkles appeared on the face of the horizontal stitch pattern sample. Even in the two samples with short vertical rows of stitches, odd shaped puffs occurred in the spaces between rows of stitching.

Three of these similar patterns will be tested in the main study along with the vertical stitching arrangement. The diagonal pattern which is used more widely than the union jack will test the effect of stitches that fall at an angle to the warp and weft of most textiles displayed vertically. Horizontal and ordered short vertical rows will complete the comparisons.

The final part of the elimination study tested the types of stitches used. The results were simple and immediately obvious. Both stitches that are sewn so that the thread pulls back on itself or pulls at an angle distorts the fabric weave when gravitation stress applied to the fabric also pulls on the stitches. The backstitch and catchstitching techniques placed in the vertical or diagonal directions produced obvious strain on the fabric when the weighting bar was inserted. The distortion was evident within ten minutes of applying the weighting, and photographs were taken to show the distortion. In the samples tested in other parts of the elimination study, the half-backstitches that had been placed after every four running stitches had to be clipped to allow the fabric to stretch without severe puckers where the stitch occurred. When no stress occurs, as in the horizontal direction in this study, the various stitches sewn across the fabric produces no noticeable stress on the weave as long as the thread is not pulled too tightly. As the sample fabric stretched lengthwise, thread sewn crosswise loosens and stands away from the fabric. In the main study, only running stitches will be used.

Main Study

The main study will consist of analyzing two factors: method of hanging and arrangement of stitches (stitch pattern). The two methods of hanging will be with a dowel in a casing hung vertically and with a dowel in a casing hung at a 5^{o} angle. The four stitching patterns are vertical, diagonal, horizontal, and ordered short vertical rows.

All the samples will be backed by yarn-dyed gingham and stitched with a running stitch. The procedures used in the elimination study will be implemented in the main study - including visual assessment.

The method of statistical analysis will be a full factorial arrangement of the treatments (three methods of hanging and four stitching patterns) with four replications. From the treatments tested, conservators can tell which is best in reducing strain on vertically hung textiles.

Notes

1 "True bias is a 45^{o} angle to any straight edge when grains are perpendicular." Reader's Digest Complete Guide to Sewing (Pleasantville, N.Y., 1976), p. 84.

2 Vicky Kruckeberg, "An Investigation of Selected Vertical Supports to Reduce Strain on Women's Outerwear While in Storage," 1979 Combined Proceedings of the regional annual meeting of the Association of College Professors of Textiles and

Clothing, Inc., pp. 104-105.

[3] AATCC Test Method 124-1978, <u>AATCC Technical Manual</u>, p. 197.

NON-WOVEN TEXTILES FOR CONSERVATION USE

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SUMMARY

In the last decade non-woven textiles have been used for various purposes in museums. This paper examines current non-woven textile products available on the market and suggests some ways in which these new products can be used for conservation purposes. Understanding the methods of production of non-woven textiles helps the user to identify the component parts of these products and to evaluate these textiles for use in conservation work. The formation of bonded, needle felt and spunbonded textiles is discussed. Differences in physical structure and properties are outlined. A simple technique of microscopic examination helps to determine if adhesive is present. New non-woven products which have not traditionally been used in a museum setting offer possibilities for conservation use. Examples of two such products are discussed.

Introduction

In the past twenty years many new processes have been developed for the formation of fabrics. Of special interest today are fabrics formed directly from fibers. The term "non-woven" or "formed fabrics" is used to include fabrics made directly from fibers or yarns where the fibers are bonded together without interlooping or interlacement of warp and filling yarns.

The purpose of this paper is to examine non-woven textiles available on the market and to suggest ways in which these new products might be used for conservation purposes. A brief description of the production methods will be given to help the user identify the component parts of the fabrics, then suggestions will be given regarding various ways to use these products in a museum setting. The conservator should better be able to evaluate these textiles for use in preventive conservation work if their production is understood.

General Production

There are three steps in the production of formed fabrics: fiber selection, formation of a web, and bonding. The starting materials for non-woven fabrics include many different textile fibers, textile yarns, filaments or films of man-made polymers. Both thermoplastic and non-thermoplastic man-made fibers are used, polypropylene, polyester, nylon and rayon being the most common.

After the fibers are chosen a web is formed by air currents which toss the fibers to give a random fiber lay, or by carding to give webs that are laid parallel or at right angles to the layers above and below. Sometimes the web is formed through a wet-lay technique, similar to that used for making paper, or the web may be formed by fibrillation of a film.

The web is usually bonded by one of four techniques. If the fibers are thermoplastic they can serve as a self-bonding material. Adhesives or a solvent which softens some of the fibers may be added to the web to adhere fibers together. The fibers may be needled, or the web may be stitched or interlocked by mechanical action. Examination of the fabrics under a microscope will help determine the method of bonding used.

The Dry Process

The most common method for producing non-woven textiles is to form a dry web. The dry web is stabilized or held together by the addition of adhesives or by heat fusion, thus, the fibers are bonded to each other at cross-over points. Most interfacing fabrics purchased at retail stores are manufactured by the dry process.

Polyester fiberfill products are battings made by a dry web method. In some products the fibers are merely entangled mechanically by carding or garnetting. In others, the web is heat bonded or adhesive bonded for added strength and dimensional stability. Fiberfill batts in which the fibers are entangled by air will have lower strength than fiber batts stabilized by adhesives. Normally low strength is not a concern when the product is used for padding a storage drawer, for making mannequins, or for padding out washed garments to aid drying.

Common adhesives used for bonding dry web products are acrylic resins, polyvinyl acetate copolymers, SBR latex, polyvinyl chloride copolymers, vinyl acetate-ethylene and polyvinylidene chloride (Obenski, Schiavone). The adhesive binder is cured or set by heat. The degree of cross-linking which occurs during the curing stage as well as the amount and type of binder affects the properties of the final product. Increases in the amount of adhesive used and the degree of cross-linking give increased stiffness in the final product. The stability of these adhesives over long periods of time, under normal museum storage conditions is not known. One can avoid problems by using textiles which are bonded by a method other than adhesives.

Examination of dry laid textiles under a microscope will show if adhesive is present. A sample of Add-Shape* interfacing shows adhesive on the fibers and at cross-over points (see Figure 1). This fabric looks and feels much like the spunbonded fabrics which will be discussed later. Thus without microscopic examination it is not possible to tell if an adhesive binder is present. Chemical solubility tests to dissolve the adhesive could also be used but are time consuming unless one knows the adhesive present. Examination of Terylene* fiberfill under the microscope shows a web with no adhesive present (see Figure 2). A comparison with a sample of an unbranded fiberfill containing adhesive shows the binder present on the fibers (see Figure 3). The hand or feel of the fiberfill samples varies also, with the presence of adhesive giving a stiffer hand. If the adhesive is sprayed onto the web, the spot welds are readily apparent at the cross-over points. If the web has been saturated with adhesive, the binder will also be present along the lengths of the fibers (Schiavone).

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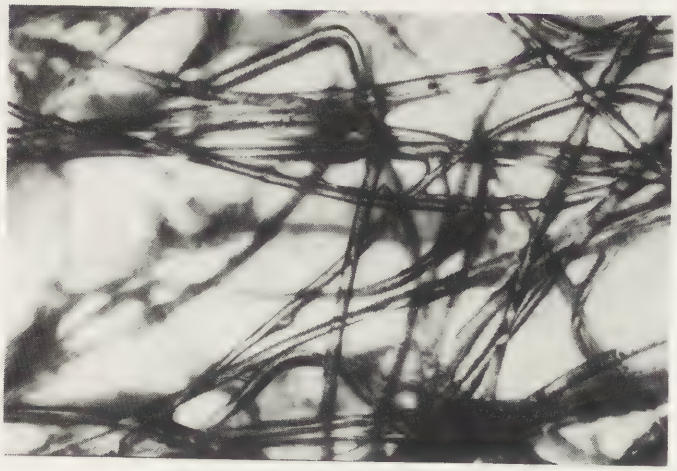

Figure 1. Add-Shape*, 100x.
Note the adhesive coating the fibers, especially at the cross-over points.

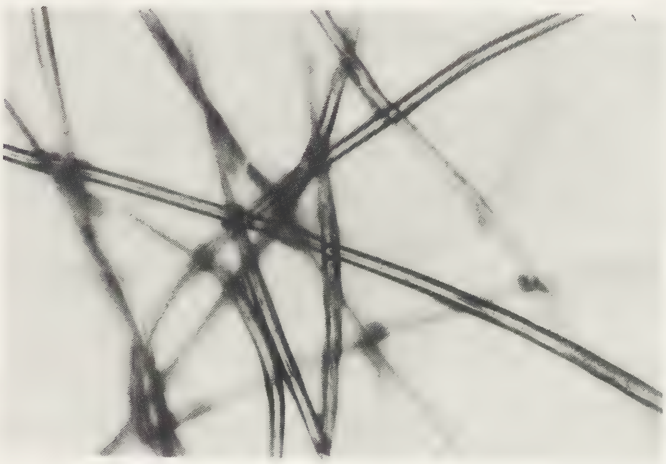

Figure 2. Terylene* fiberfill, 100x.
No adhesive present.

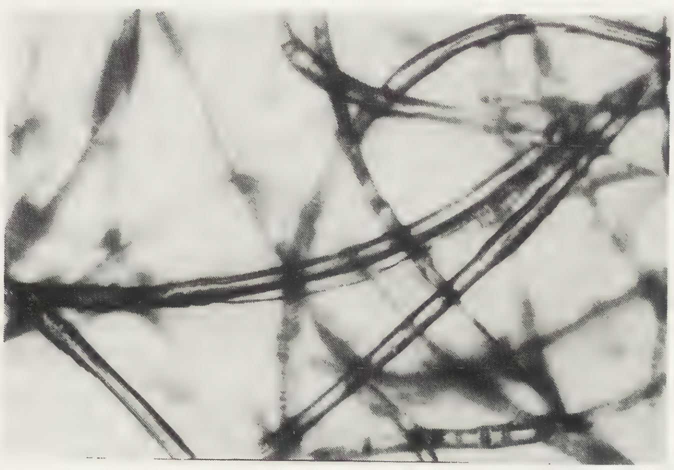

Figure 3. Unbranded fiberfill, 100x.
Adhesive present.

Needle Felting

Needle felting is a method of mechanically interlocking loose fibers to form a felt or fabric (Eichorn). It differs from the traditional form of wool felting in that fibers without scales are used and that barbed needles are used to interlock or tangle the fibers together. The fibers are arranged into a web or bat by mechanical or air-lay systems. The fibers may be arranged randomly or parallel in the web. A scrim or set of yarns may be placed in the center between two webs to increase the strength and durability. The bonding of fibers is done by barbed needles, much like the barbs on the end of a fish hook. As the needles move through the layers of fibers, the barbs push the fibers into a distorted and tangled arrangement. The fabrics are characterized by an intimate three dimensional fiber entanglement. Usually needle holes are also visible. An adhesive is not used to hold the fibers together.

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An example of needle felted fabrics are Mirafi* fabrics manufactured by Dominion Textiles Inc. and normally used to reinforce roads or provide drainage. These fabrics are called geotextiles in the industry. Mirafi* fabrics are 100% polyester; they vary in thickness from 2.0 mm to 4.1 mm and weigh from 200 to 680 gm/square meter (Dominion Textiles Inc.). The heavier weights could be used for lining storage drawers. The light weight fabrics might be used as the first layer of padding on mannequins or any place where wool felt may have been used. Examples of uses in mounting are padding of a sealed wooden frame before mounting fabric is attached or in framing to keep the matt board off the mounting fabric. The fabrics are not as soft or resilient as fiberfill batting, but they are much cheaper. The fabrics are manufactured in 3.5 meter widths - much wider than most traditional products now used.

A specific example of the successful use of needle felted geotextiles is for lining storage drawers holding beaded dresses from the 1920's. The needle felt was placed on the cotton muslin liner of a wooden drawer or directly on the bottom of a metal drawer and covered with light acid free tissue or a spunbonded fabric. The needle felt serves to cushion the beads of the beaded dress.

Spunbonded Fabrics

Spunbonded fabrics are made directly from molten polymer as continuous filaments that are self-bonded at each cross-over point. The fiber is extruded through the spinnerets, is drawn to introduce molecular orientation and strength, and is collected on a moving surface to form a web (Joseph). The filaments fall in a random fashion as they are fed onto the conveyor belt. Heat and pressure is applied to melt the filaments together at cross-over points. The amount of melting or fusion at the cross-over points will vary with different products (see Figure 4). An adhesive is not used to hold the fibers together.

Spunbonded fabrics have high strength, approximately equal in all directions. They are non-ravelling, resist distortion and do not tear readily. Examples of spunbonded fabrics are Remay*, a polyester fabric and Tyvek*, a polypropylene fabric manufactured by DuPont, and Cerex*, a nylon fabric made by Monsanto (see Figures 5 and 6). The fabrics come in varying weights, from 3.5 to 70 gms/sq meter. The lighter weight fabrics have been distributed by museum supply houses in the United States for a number of years and have been used by paper conservators.

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A good use for these fabrics is in the flat storage of textiles and costumes. They can be used to separate textiles, to pad or wrap around costumes and as support for light weight flat items.

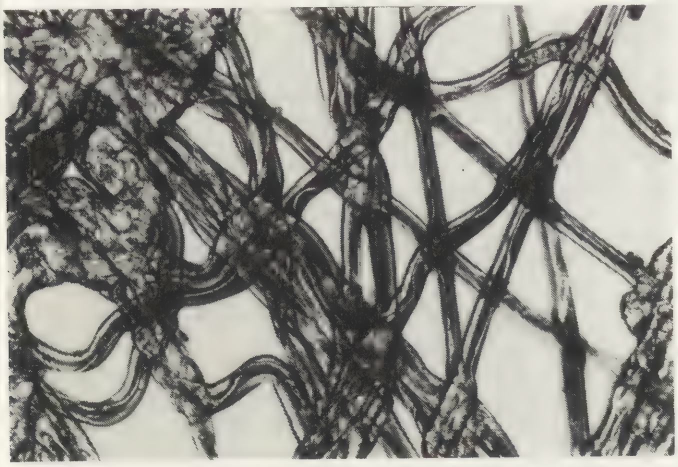

Figure 4. Hollytex polyester spunbonded fabric, 100x.
There is a high degree of melting at the cross-over points of the filaments in this fabric.

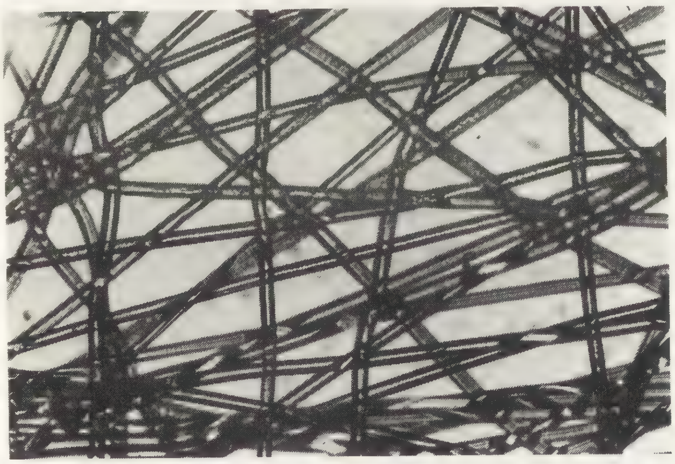

Figure 5. Cerex* nylon spunbonded fabric, 10 gm/m^2.

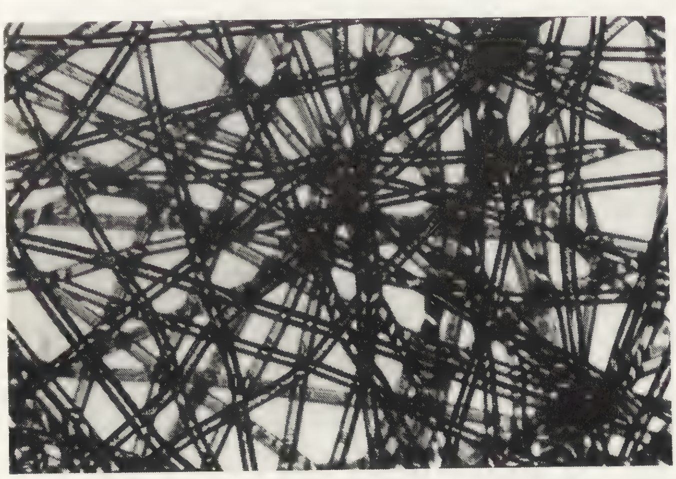

Figure 6. Cerex* nylon spunbonded fabric, 34 gm/m^2.

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After completion of a conservation project at the Provincial Museum of Alberta in Edmonton and as a result of work in the Historic Costume and Textile Study Collection at the University of Alberta, we have found that spunbonded fabrics can be used in many places acid free tissue is used. Certainly the fabrics are more expensive than acid free tissue, but they do not become brittle on ageing and they are much stronger. The fabric is washable so it can be reused. If the humidity in the storage area falls below 20 percent, static electricity may be present as the spunbonded fabrics are unrolled from the supply rolls.

Some laminating fabrics used in paper conservation are spunbonded fabrics with an adhesive on one or both sides. Promato* Heat Set Tissue from Process Materials is an example. Stitch-Witchery*, available in retail stores, is an example of a fusible interfacing which is a spunbonded fabric with an adhesive. These products are not recommended for storage of textiles.

Other Textiles

Geotextiles are woven and non-woven textiles used in civil engineering applications: reinforcing highways, in dams, canals and drains. While examining these new textile products, ideas for their use in textile conservation work emerged. One example, the Mirafi* needle felt fabrics were discussed previously.

In setting up the textile conservation laboratory at the University of Alberta screens were needed for washing textiles. Various weights of nylon netting and traditional glass fiber screening have been used. With textiles which become very heavy when wet, we were dissatisfied with glass fiber screening. It tended to stretch slightly and thus sag in use.

A drainage product, received as a geotextile sample, looked like a promising screen material for conservation. TENSAR* is a high density polypropylene grid fabric manufactured in England by Netlon Ltd. (see Figure 7). It is smooth, rigid and light weight. The openings vary in size and shape in the various products. They are small enough to support a heavy textile yet large enough to allow for the free flow of detergent foam in cleaning and rinsing. The edges have to be bound with twill tape and any rough openings can be sanded to ensure the fabric does not snag the textiles being washed. A traditional glass fiber screen could be used on top of the geogrid.

Another geotextile which is a good screening material is a polyester net fabric manufactured by Bay Mills Ltd. and sold by the Mercantile Development Inc. of Westport, CT. Originally used to reinforce asphalt and to make fences to hold in soil, it is soft and flexible. The openings between the filaments are larger than openings in most commercially available netting. Thus rinsing in wet cleaning is easier as the detergent foam is not retained by small sized openings as in fiberglass screenings or in net. The fabric would be used with light weight textiles. The fabric is available in a white or gray color and is manufactured with various size openings (see Figure 8).

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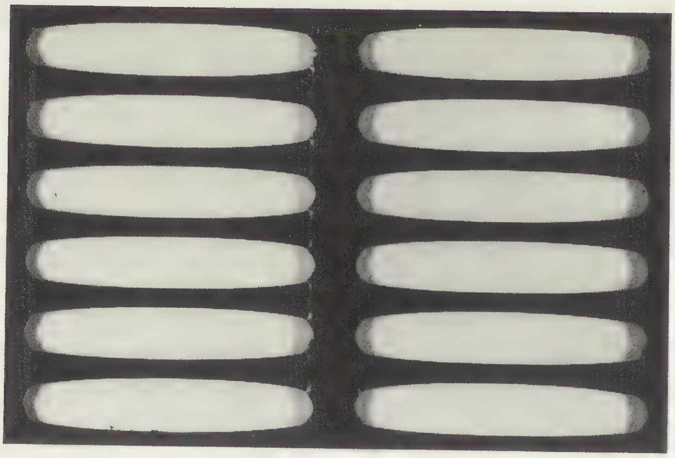

Figure 7. TENSAR* SR1, polypropylene geogrid.
The openings are 1 cm x 5 cm.
Other styles have larger openings.

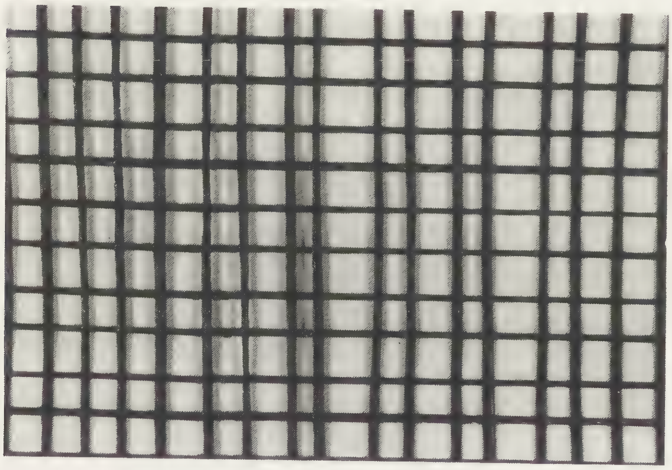

Figure 8. Geofab* polyester net.
Fabric count 11 x 11 per 2.5 cm.

Conclusions

There are many new non-woven or formed textile fabrics which a textile conservator could find useful. By understanding how these textiles are produced the conservator should better be able to evaluate the products for conservation use. As production methods are understood technical literature which comes with non-woven products should be easier to evaluate.

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FIRE RETARDANT FINISHES FOR FIBER ART: A CONSERVATION PERSPECTIVE. PRELIMINARY FINDINGS

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SUMMARY

Fire safety regulations in Canada usually require that decorative materials in public buildings be capable of passing a vertical flame test either through inherent characteristics or the presence of a fire retardant finish. Fiber art structures are frequently subject to this regulation because of their form and scale. This research investigates the effect of three water soluble fire retardant agents, borax/boric acid/diammonium phosphate, FlameGard DSH and X-12 on the physical properties of a 100% cotton substrate. The add-on necessary for fabric to pass the vertical flame test was determined as well as change in dimensional stability, flexural rigidity, tensile strength, colour and pH. To assess long term effects of the agents, treated fabrics were subjected to accelerated aging in an Atlas Weatherometer with carbon arc. From a conservation perspective, all three agents possess some shortcomings. Dimensional changes were minimal and fabric pH after treatment was acceptable. Loss of stiffness was less marked at 21% RH than under standard conditions (21°C and 65% RH). Untreated fabric and borax/boric acid/DAP treated fabric became whiter after accelerated aging, however, the other two agents caused the cotton to become brown. When dyed fabrics were treated, borax/boric acid/DAP caused more colour change than the other two agents.

Introduction

This research was initiated in response to a perceived need in the fiber arts and museum communities. Specifically, museum textiles have on at least one occasion received improper and damaging fire retardant treatment; in addition, fiber arts instructors at Alberta colleges were anxious for more information for teaching purposes. The research was narrowed to the study of three fire retardant treatments on a cotton substrate using the immersion method of application. Cellulosic material was selected for treatment because it is the most dangerously flammable of the textile fibers and because it is widely used by fiber artists. The fire retardant agents examined are suitable for cellulosics and because of their availability and ease of application, are likely to be used by fiber artists in North America.

Justification for the Study

In recent years fire safety codes relating to textiles in public buildings have become increasingly restrictive; awareness and enforcement of the regulations is also increasing. In Canada legislation of fire safety is a provincial government concern. The National Fire Code of Canada provides "a model set of technical requirements designed to provide an acceptable level of fire protection and fire prevention in a community" (1). Legislation of an Alberta Fire Code based on the National Code is expected in 1984. Thus it is expected that fiber arts which may not have met fire regulations in the past will need fire retardant treatments to enable them to meet the requirements of the new legislation. Furthermore, the increased use of fiber art in public buildings (2, 3) suggests that there will be a greater need for fire retardant treatments on textiles of cultural and artistic significance than in the past. Contemporary fiber art works produced by leading artists are valuable in both the cultural and economic sense. Preventive conservation of these pieces is becoming a concern to the textile conservator. It is to be expected that the future will bring more requests for help in preserving relatively new textiles. Contemporary fiber art works contain a variety of conservation problems ranging from damage due to improper mounting techniques and environmentally induced degradation to the use of unsafe finishing treatments or incompatible materials. Fire retardant finishes, in fact, have frequently been sited as causing degradation of fibers over an extended period of time (4, 5, 6). The topic of this study is just one of the concerns of the textile conservator charged with the preservation of fiber art.

Objectives of the Study

The major objectives of the study are (1) to evaluate the suitability of three selected fire retardant finishes for use on fiber art; (2) to make recommendations regarding the selection and use of fire retardant agents to fiber artists and textile conservators involved with large scale fiber commissions or installations in public buildings; and (3) to provide information to textile conservators who may find themselves working with textiles that have been given fire retardant finishes.

Selection of Treatments

A review of the pertinent literature illustrated the relatively limited number of chemical compounds suitable for application to fiber art works (7). Whilst a number of inorganic compounds can be expected to prevent flame propagation if present in large enough amounts, they are not generally regarded as efficient agents due to the excessive add-on required which has detrimental effects on the character of the textile (4). In addition, the fire retardant compound must be able to prevent afterglow in cellulosics as well as flame propagation. The durable and semi-durable treatments available on the market were not chosen for study because they are essentially geared towards large scale mill applications with specialized equipment and require critical time and temperature control during curing operations. They are unlikely to be of use to the fiber art community except when the artist can work with purchased, commercially treated yarns and fabrics. At the moment it appears that research on new fire retardant agents is diminishing (8). Thus, artists are relying upon a relatively limited number of non-durable water soluble chemicals and proprietary reagents currently available on the market.

From the twelve suppliers listed in the 1982 Manual of the Textile Industry of Canada one suitable proprietary reagent, FlameGard DSH

was located. It is produced by Jersey State Chemical Co. in the United States and is supposedly composed of inorganic ammonium salts. Chemical analysis by the National Research Council's Edmonton laboratory shows the reagent to contain a major amount of chlorides, and some sulfate and phosphate. Elements identified were bromine, boron, and sodium. The reagent was supplied courtesy of Tanatex/Sybron Canada Ltd.

Another reagent known as X-12, formerly manufactured by DuPont, was supplied courtesy of Spartan Adhesives and Coatings Co., Crystal Lake, Illinois, U.S.A. Chemical analysis indicated this reagent contains a major amount of sulfur and a minor amount of phosphorus. Information in the literature suggests this reagent is mainly ammonium sulfamate, a reagent which may have undesirable side effects on the fabric when it decomposes (5).

In addition, a treatment using borax, boric acid and diammonium phosphate was prepared in the laboratory from a formula in the "Fire Protection Handbook" (9), a publication of the U.S. National Fire Protection Association. Various formulations using borax and boric acid have been published as treatments which can be prepared and applied at home, however it has been reported that loss of strength can occur if these reagents remain on cotton fabric for a long period of time (6).

Experimental Work

Fabric selection and preparation: Since each fiber art work is a unique combination and manipulation of materials it was not considered useful to try to simulate a fiber art structure. In order to obtain a controlled and reproducible substrate for testing, a plain weave, unbleached, desized 100% cotton print cloth was obtained from Testfabrics, Inc. It had a mass of 120 g/m^2 and a yarn count of 35 x 32/cm (warp x weft). Four lengths of fabric 150 x 70 cm were cut and labelled with control and treatment numbers. Measurements for dimensional change in wetting, as specified in CAN2-4.2-M77, Test Method 25.1-1977 (10) were marked on the fabric with grey silk thread. The fabric was then ready for treatment. Coloured samples were prepared by dyeing swatches of fabric with Procion fiber reactive dyes in red, yellow, blue, orange, green and purple.

Preparation and application of fire retardant finishes: Preliminary experimentation indicated the solution concentration which provided an add-on sufficient for the fabric to pass the vertical flame test (CAN2-4.2-M77, Test Method 27.1-1977). Specimens were treated with two proprietary agents, FlameGard DSH and X-12, and a non-proprietary agent, borax/boric acid/diammonium phosphate (DAP). Distilled water and a wetting agent (J Wet FR) were used to prepare each solution. It should be noted that the level of add-on required depends on the weight and construction of the fabric; a heavy weight cotton fabric requires a lower add-on than a light weight fabric.

A control fabric was prepared by wetting out the test fabric in distilled water plus 1% wetting agent, then drying it flat. The pH of the bath was 7.6. The borax/boric acid/DAP treatment consisted of 7:3:5 parts by weight of borax:boric acid:DAP in 110 parts water with 1.5% wetting agent. Solution pH was 8.4 and a 15% add-on was achieved after three immersions. The X-12 finish was a 18% (W/W) solution with 1% wetting agent. The solution pH was 6.7. An add-on of 15.2% was required for fabric to pass the vertical flame test. FlameGard DSH was prepared as a 20% (V/V) solution with 1% wetting agent. The solution pH was 8.2 and an add-on of 10.7% was required.

The treatments were prepared according to manufacturers' specifications and applied by immersing the fabric in the solution then drying it flat with the aid of a cool air fan.

Sample preparation: When it was established that the fabric would pass the vertical flame test, samples were cut for testing. No two specimens in the same test contained the same warp and weft yarns and no specimens were cut within 15 cm of the selvedge.

Accelerated aging: Specimens were subjected to accelerated aging in order to determine the long term effects of the fire retardant agents, particularly to determine whether loss of strength would occur. Accelerated aging was carried out in an Atlas Weatherometer by exposing the specimens to continuous light from a carbon arc lamp at a temperature of 60-65°C and relative humidity of 20-35%. Pretesting indicated that 478 hours of accelerated aging imparted a 48% strength loss to untreated fabric.

Test procedures: Specimens were tested under standard conditions of 21 ± 2°C and 65 ± 2% RH. The following Canadian Government Specifications Board test methods were used: CAN25.1-1977(Dimensional Change in Wetting), CAN27.1-1977(Vertical Flame Test) and CAN5.A-1977(Fabric Mass). Fabric stiffness was assessed by ASTM Test Method D1388-64 (Flexural Rigidity). Measurement and calculation of colour differences in CIELab units were made with a Hunterlab Model D25M/L tristimulus colourimeter. Aqueous extract fabric pH was determined with a Fisher Accumet Model 230 pH meter.

RESULTS AND DISCUSSION

The results obtained to date and listed in Table 1 show the short term effects of the fire retardant treatments on fabric properties.

When treated fabrics were stored under standard conditions prior to testing it was noted that the borax/boric acid/DAP finish leached out and crystallized on the surface of the fabric. In addition, the fabric treated with FlameGard DSH was noticeably hygroscopic and felt damp to the touch.

Dimensional stability: It can be seen in Table 1 that shrinkage after treatment varied in the warp direction from 1.4% for water alone to 0.6% for FlameGard DSH and from 0-0.8% in the weft direction. The results of this test suggest that changes in dimension of the fabric are caused by the wetting action of the water. The presence of the fire retardant agents in solution appears to reduce the shrinkage caused by water. Normally a 3% maximum change in dimensions is acceptable after fabrics such as draperies are cleaned (11). Where a fiber art work is concerned, however, the dimensional change which the artist considers acceptable will vary depending upon the scale of the work and the method of installation. If the artist expects dimensional change to occur after treatment with a fire retardant agent this fact will likely be taken into account when the art work is being designed.

Table 1 Dimensional Change, Flexural Rigidity and pH of Cotton After Treatment with Fire Retardant Agents[a]

Agent[b]	Dimensional change (%) warp	Dimensional change (%) weft	Flexural rigidity[c] (% change) standard	Flexural rigidity[c] (% change) ambient	Fabric pH
water	-1.4	-0.8	-12.4	-19.5	7.1
B/BA/DAP	-1.1	-0.7	-26.5	- 2.8	7.3
X-12	-0.7	0.0	-23.6	- 9.4	6.5
DSH	-0.6	0.0	-38.1	-20.1	5.5

[a]Dimensional change, mean of 6 measurements; flexural rigidity, mean of 16 measurements; pH, mean of 5 specimens.

[b]B/BA/DAP, borax/boric acid/diammonium phosphate; X-12, Spartan Adhesives & Coatings Co.; DSH, FlameGard DSH, Jersey State Chemical Co.

[c]Under standard conditions (21°C, 65 ± 2% RH) Under ambient conditions (21°C, 21% RH).

Flexural rigidity: Fabric stiffness was determined by the flexural rigidity test which is a measure of the interaction between fabric weight and fabric stiffness as shown by the way a fabric bends under its own weight due to the force of gravity. It is just one component of drape. Flexural rigidity was measured under both standard and ambient conditions because the standard relative humidity of 65 ± 2% is considerably higher than that which occurs in many areas of the country. The results obtained under standard conditions are shown in Table 1. The stiffness of the fabrics was considerably reduced by the flame retardant finishes, the greatest change occurring from FlameGard DSH which caused a 38% loss of stiffness. Under ambient conditions (21% RH), fabric treated with FlameGard DSH behaved in a similar manner to the control fabric which had only been exposed to water, both exhibiting a loss in stiffness of about 20%

Flexural rigidity has been shown to produce an excellent correlation with subjective evaluations of fabric stiffness. A 10% difference in flexural rigidity is reported to be the lowest level capable of being detected subjectively (13). Although a scientific test for fabric hand and stiffness was not conducted, subjective evaluation by co-workers was done at 21% RH. Fabric treated with borax/boric acid/DAP had a crisp hand, X-12-treated fabric felt less stiff and DSH-treated fabric was closest to the original. For the fiber artist, this change may vary in importance. If an art work relies on manipulation of fabrics in three dimensions, loss of stiffness may alter the artistic concept; a two dimensional piece, however, is less likely to be adversely affected by a loss of stiffness.

pH of treated fabrics: The pH of treated fabrics before accelerated aging are shown in Table 1 and indicate that the control fabric remained nearly neutral after wetting out with water. Fabrics treated with borax/ boric acid/DAP and X-12 were also close to neutral. Although the FlameGard DSH solution is basic (pH 8.2) the fabric had an acidic pH of 5.5 after treatment. The pH of treated fabrics after aging will be reported later.

Table 2 Effect of Fire Retardant Treatment and Accelerated Aging[a] on Colour of Undyed Cotton

Treatment[b]	State	Colour change[c] (CIELab units)	AATCC Gray Scale rating
Water	Unaged	0	5
	Aged	2.49	3-4
B/BA/DAP	Unaged	1.16	4-5
	Aged	1.63	4
X-12	Unaged	1.06	4-5
	Aged	11.08	1
DSH	Unaged	0.68	4-5
	Aged	13.43	1

[a]Specimens irradiated with carbon arc lamp for 21 days at 60-65°C, 20-35% RH.

[b]B/BA/DAP, borax/boric acid/diammonium phosphate; X-12, Spartan Adhesives & Coatings Co.; DSH, Flame Gard DSH, Jersey State Chemical Co.

[c]Average of five measurements before aging; ten measurements after aging.

Colour change: The colour changes of undyed treated fabrics before and after accelerated aging appear in Table 2. In order to give meaning to the numerical values for colour change, an AATCC Gray Scale rating has also been included. A verbal description of the Gray Scale ratings appears in Table 3. For the purpose of this study, a Gray Scale rating of 4 has been selected as the minimum acceptable level of colour change and is the criterion against which the colour changes have been evaluated. It should be noted that the minimum acceptable colour change rating for drapery fabrics exposed to light (xenon arc) is a class 4 colour change according to ASTM Method D3691-78 (11). Undyed fabrics treated with the fire retardant finishes varied in their response to the conditions of accelerated aging. The heat, light and moisture caused fabrics treated with X-12 and FlameGard DSH to become light brown in colour. It is possible that the intense light from the carbon arc lamp caused one agent in these formulations to darken. The borax/boric acid/ DAP-treated fabric appeared whiter after aging although this change was less pronounced than that observed in the control fabric. The radiation from a carbon arc lamp is similar but not identical to visible light, thus, it is difficult to predict whether the colour changes seen during accelerated aging would occur during natural aging.

The colour changes which occurred when the dyed swatches were treated with flame retardant agents are reported in Table 4. It can be seen that no particular treatment caused a marked colour change in all dyed fabrics. The borax/boric acid/DAP finish, for example, caused a noticeable change in the red, blue and orange swatches. FlameGard DSH and X-12 caused a noticeable change in the blue samples. These results are only applicable to the particular Fiber Reactive dyes used in this experiment and simply provide the artist with a general indication that colours may be altered by fire retardant treatments.

Table 3 Relationship of Colour Change in CIELab units to AATCC Gray Scale Ratings with Verbal Description

CIELab units	AATCC Gray Scale ratings	Verbal Description
0.0 ± 0.2	5	negligible/no change
0.8 ± 0.2	4-5	
1.7 ± 0.3	4	slightly changed
2.5 ± 0.35	3-4	
3.4 ± 0.4	3	noticeably changed
4.8 ± 0.5	2-3	
6.8 ± 0.6	2	considerably changed
9.6 ± 0.7	1-2	
13.6 ± 1.0	1	much changed

Table 4 Effect of Fire Retardant Treatment on Colour of Cotton Dyed with Procion Fiber Reactive Dyes

Hue	Fire retardant treatment[a]	Colour change[b] (CIELab units)	AATCC Gray Scale rating
Yellow	B/BA/DAP	0.32	5
	X-12	1.11	4-5
	DSH	1.01	4-5
Red	B/BA/DAP	2.20	3-4
	X-12	1.55	4
	DSH	1.52	4
Blue	B/BA/DAP	3.20	3
	X-12	2.38	3-4
	DSH	2.56	3-4
Green	B/BA/DAP	0.54	5
	X-12	0.97	4-5
	DSH	1.10	4-5
Orange	B/BA/DAP	3.18	3
	X-12	1.04	4-5
	DSH	1.74	4
Purple	B/BA/DAP	1.20	4-5
	X-12	1.94	4
	DSH	1.34	4

[a] B/BA/DAP, borax/boric acid/diammonium phosphate; X-12, Spartan Adhesives & Coatings Co.; DSH, FlameGard DSH, Jersey State Chemical Co.

[b] Average of five measurements.

CONCLUSIONS

From a conservation perspective, the three flame retardant finishes which were examined all possess some shortcomings. Considering the results available at this time, it is not possible to recommend one particular treatment. FlameGard DSH required a low add-on for the fabric to pass the vertical flame test. It caused negligible dimensional change and when applied to various dyed swatches, it altered the colour of only the blue swatch. Treated samples were limper when fabric stiffness was measured under conditions of high humidity. The undyed fabric became a light brown colour after aging perhaps because of the reaction of some agent in the finish to radiation from the carbon arc lamp. The slight acidity of the fabric after treatment (pH 5.5) may prove to be damaging over an extended period of time.

The second treatment, X-12, required a much higher add-on than FlameGard DSH. Although it also caused minimal dimensional change it turned brown during accelerated aging. Loss of stiffness was less noticeable than with FlameGard DSH.

The borax/boric acid/DAP treatment also required a high add-on and the difficulty of achieving it makes the application of this reagent more stressful to the fiber art work than other treatments. It changed the colour of several dyed swatches noticeably, a result which may concern the fiber artist. This treatment was the only one which did not darken the fabric during accelerated aging. In addition, the pH level at 7.3 was most acceptable for a cotton substrate. Under ambient conditions the treatment stiffened the fabric and gave it a "chalky, crispy" hand. When fabric was stored under standard conditions (65% RH, 21°C) the fire retardant chemicals leached out or migrated to the surface in an unacceptable manner. The effect of the leaching on flame resistance has not been tested thus far. If the fabric cannot pass the flame test after leaching occurs the finish should not be used.

From the preliminary results, it appears that none of the reagents in the study can be considered suitable from a conservation perspective. The fiber artist who has to apply a FR treatment in order to install a work of art must, therefore, consider evaluating any proposed treatment on the basis of what changes can be most readily accepted.

SUPPLIERS

Cotton fabric: Testfabrics, Inc.
P.O. Drawer O
200 Blackford Avenue
Middlesex, NJ 08846, USA

FlameGard DSH: Tanatex Division
Sybron Canada Ltd.
120 Norfinch Drive, Unit 1
Downsview, Ontario M3N 1X3, Canada

X-12: Spartan Adhesives & Coatings Co.
345E Terra Cotta Avenue
P.O. Box 395
Crystal Lake, Il 60014, USA

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THE STUDY OF THE EFFECTS OF WET-AND DRY-CLEANING OF WOOL ARTIFACTS

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National Museums of Canada

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SUMMARY

To determine whether dry-cleaning has an adverse effect on the properties of wool artifacts, the lanolin in Corriedale wool was extracted with petroleum ether in Soxhlet apparatus.

Degreased and natural wool were subjected also to ageing due to UV irradiation and elevated temperature. Differential scanning calorimetry and thermomechanical analysis did not detect any differences between the degreased and natural wool. Elastic properties of degreased wool were found to be inferior to natural wool, but this is suggested to be due to exposure to elevated temperature during extraction, rather than to the absence of lanolin.

The obtained results do not support the view that the dry-cleaning of wool artifacts without heat is harmful.

1. Introduction

No agreement exists among conservators regarding the best method for cleaning artifacts. In commercial practice, dry-cleaning is preferred method for cleaning of articles made of wool. Because of the excellent grease dissolving ability, color retention, and the absence of felting dry cleaning was recommended by some authors also for the use in conservation practice.(1,2)

Other experts are of the opinion that dry-cleaning is harmful because the removal of wool fat (lanolin) by the cleaning solvent renders the completely degreased wool yarn brittle. Hermann Rath the author of a widely read textbook of textile chemistry while emphasizing the need to remove most of the lanolin to avoid tackiness and facilitate spinning, recommends to retain approximately 1% fat on the fibers to preserve good elastic properties.(3)

Similar views are held by textile conservators.(4). The results of experiments of Leene and coworkers indicated that washing wool with soap or with anionic and nonionic detergent is harmless, but extraction with diethyl ether and dichloromethane causes heavy damage in wool aged at high humidities but with exclusion of light.(5)

At the last Triennial Meeting of ICOM(6)Landi discussed the need for an accelerated aging test to detect the changes resulting from dry-cleaning due to the possible retention of the cleaning solvent or detergents by the fibers.

To determine the effect of degreasing on the wool fibers thus appeared to be warranted and the present work was undertaken.

2. Experiment

In order to eliminate the effect of agents used in industrial processing of yarn (e.g. bleach, mordant Cr_2O_3, dye, moth proofing agents: organic fluorides, alkaloids, shrink proofing resins etc) untreated natural 100% Corriedale wool (derived from a merino cross breed in New Zealand) was used in the experiments. After spinning locally the yarn was washed in four changes of soapy water and rinsed in three changes of water. To the last rinse some fabric softener (Downy made by Proctor and Gamble) was added.

The washed yarn was divided into two portions with one batch used in this condition, and the second subjected to petroleum ether extraction in a Soxhlet apparatus for 5 hours. This extraction has yielded 1.44% wool fat.

Samples of both batches of wool were then exposed to artificial aging in UV light. Samples were removed after 164, 332 and 500 hours of irradiation.

The wool filament specimens were aged in a Q.U.V. Accelerated Weathering Tester (the Q-Parnel Company) containing a bank of eight special fluorescent lamps, 40 Watt each. The lamps produce UV light in the region between 280 and 360 nm wave length with the peak intensity occuring at 310 nm. The UV stress obtained with the lamps emitting UV-B is comparable to noon midsummer light on a clear day. Irradiation was continuous for 500 hours and high 100%relative humidity in the chamber was provided by maintaining a pool of water.

A DuPont Model 1090 Thermal Analyzer with a differential scanning calorimeter (DSC) was used under inert N_2 atmosphere for the determination of the heat effects.

The determination of the elastic properties was performed in an Instron Model 1122 testing machine. The 125 mm long specimens which have been conditioned at 55% R.H. were held by air pressure activated clamps. The extension was measured to 0.1 mm.

Structure of wool.
A very brief description of the structure of wool is given here to facilitate the discussion.

The external surface of animal hair is called cuticle consisting of unpigmented transparent overlapping scales the free margins of which are oriented toward the tip of the hair. Identification of hair if possible is usually based on features of the size, shape and arrangement of the scales which are often unique to the animal species.

The main body of the hair, constituting 90% of the fiber mass and covered by the cuticle, is called cortex It is composed of axially elongated cells which are densely packed microfibrils preferentially oriented parallel to the fiber axis.(7)

Low sulfur containing α helical polypeptide chains are the building blocks of microfibrils. Two or three helices twined together in a rope-like fashion form the keratin chain. In addition, the microfibrils contain also a sulfur rich amorphous matrix.

Two types of cortical cells exist in wool: para-and orthocortex. In fine wool these cells show bilateral symmetry with the paracortex being inside of the crimp and the orthocortex on the outside, and therefore, is longer.

The physical properties of the two types of cortical cells show distinct differences.

Orthocortex built of fewer cystine molecules in the protein chain and is surrounded with less matrix, has a lower sulfur content than paracortex. Because of fewer basic and acidic aminoacid endgroups in paracortex it is less reactive chemically than orthocortex, and also shows reduced affinity to dyes. The heat stability of paracortex is lower than that of orthocortex.

2.1. Differential scanning calorimetry

The thermograms of the natural and degreased yarn specimens aged for 0, 164, 332 and 500 hours at high humi-

dities and in UV light, are shown in Fig.1.

In both sets of curves a broad endotherm peak is observable between 40° and 200°C which is due to evaporation of water.(8) The free water covering the filament is driven off between 40° and 120°C while above this temperature water linked to hydrophilic sites of wool are released. (The extension of the curve to 200°C is the result of delayed registration of evaporation owing to the high 20°C/min heating rate.)

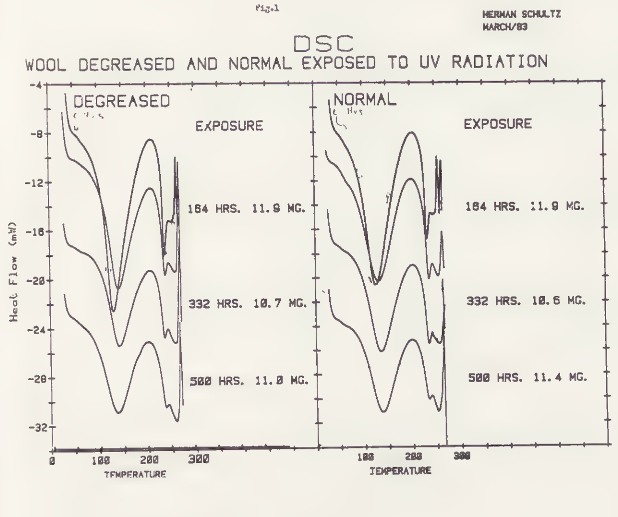
A change in the ΔT baseline at 165°C observed previously (8) and interpreted as an indication of a sudden change of entropy, due to glass transition in the amorphous component of the fiber is not apparent in the present results probably because with the moisture content and heating rate selected an effect of glass transition was masked by the large endothermic peak.

In the temperature region between 220°and 260°C a doublet appears in the thermograms of every specimen tested. The first endothermic peak occurs between 220° and 245°C and was attributed by Crighton and Happey to melting of the paracortical structure, while the second peak between 245°and 260°C to melting of the orthocortical structure. These melting processes are effected by the cleavage of the disulfide bonds of the cystine aminoacid.

In the thermograms of the non-irradiated specimens the low temperature peak is more pronounced than that occurring at higher temperatures. With increasing length of UV irradiation the low temperature peak diminishes and the high temperature peak increases in size. After 164 hours of irradiation, the two peaks are approximately equal in size, but after 332 hours the high temperature peak becomes more pronounced and after 500 h the low temperature peak is only a shoulder of the dominant high temperature peak.

The obtained thermograms lead to the conclusions that while definite aging occurs on irradiating wool fibers at high humidities there is no difference detectable by the DSC method between the degreased and not degreased wool.

Fig.1



2.2. Thermomechanical Analysis.

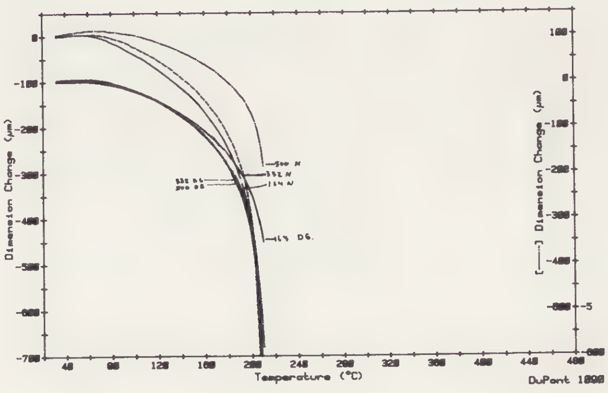
The dimensional changes of the wool specimens aged for various length of time during heating to 240°C are shown in Fig. 2.

Because the fiber is under stress, the curves indicate little change of length up to approximately 80°C, above which temperature gradual contraction occurs that reaches appr. 10% at 180°C. No difference can be detected in the curves due to exposure to UV light or due to degreasing.

The contraction is thought to be caused by the melting of the amorphous fraction of the wool, which constitutes approx. 80% of the total mass.(9)

Fig.2

TMA



2.3. Elastic Properties.

The elastic properties of wool subjected to Soxhlet extraction were compared with those of natural and aged wool fibers.

Half of the natural and half of the extracted skein portion was subjected to accelerated aging tests, (10) keeping them in oven at 57°- 58°C (135°F±2°) for six hours. At the beginning of the second, third, fourth fifth hours of aging all ports were closed and 20 cubic centimeters of water were added for each cubic foot of oven capacity. The ports were opened again after 5 minutes.

After aging the fibers were conditioned at 21°C±1°C and 65% RH as specified for textiles.

The elastic properties of the conditioned fibers were tested according to A.S.T.M. D 1774-79 (11). The gauge length for the yarn test was 125 mm. The crosshead speed of tensile machine was 10mm/min and the chart speed 100 mm/min.

After clamping the sample ends in the testing machine a 50 g load as pretension was applied to remove any crimp (slack) from the fiber. By rezeroing the instrument, the effect of the pretension was eliminated from the curve.

The testing machine was started and stopped when 10% elongation has been reached. A 60 second waiting period was allowed for the stress to decay. The motion of the crosshead was then reversed to travel at the same rate as in the extension cycle. After 3 minutes of relaxation the fiber was again extended at the same rate.

Six specimens, each of the natural and degreased fibers, both aged and not aged, a total of 24 were initially tested.

In Fig. 3 to 6 the averaged results obtained with the four groups of 6 test samples are shown.

The first non linear part of the stress-strain diagram (left of AB) represents the elastic elongation. This extension is completely reversible and its relative magnitude is one of the distinctive features of good garment wools. When stretched beyond the limit of elastic elongation, the yarn undergoes plastic deformation probably due to changes in the structure of keratin molecules, (12)i.e. upon releasing the stress the yarn will not revert to its original length. The degree of restoration of original dimension depends on the proportion of the elastic component of the elongation.

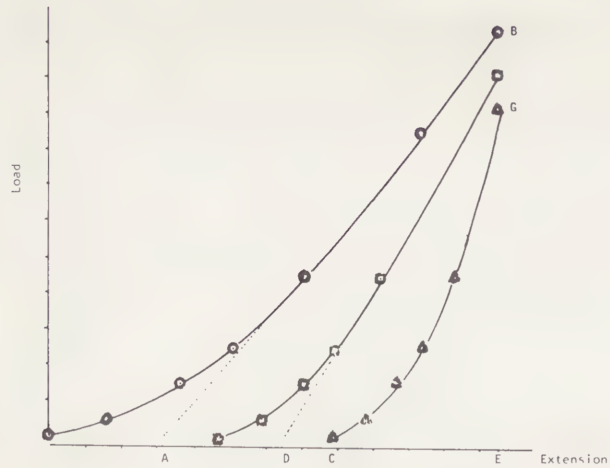


FIG. 3 Elastic properties of natural wool

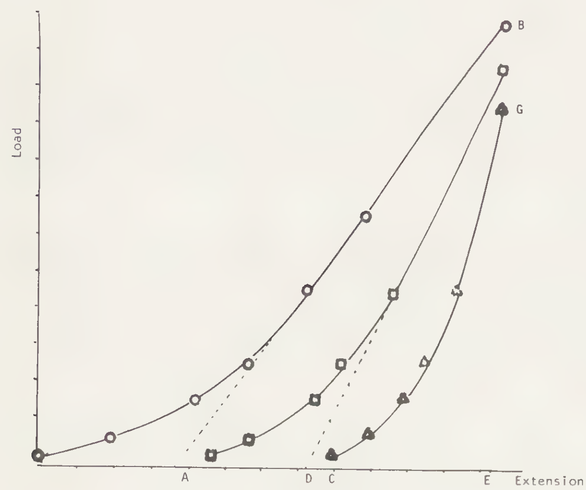


FIG. 4 Elastic properties of aged natural wool

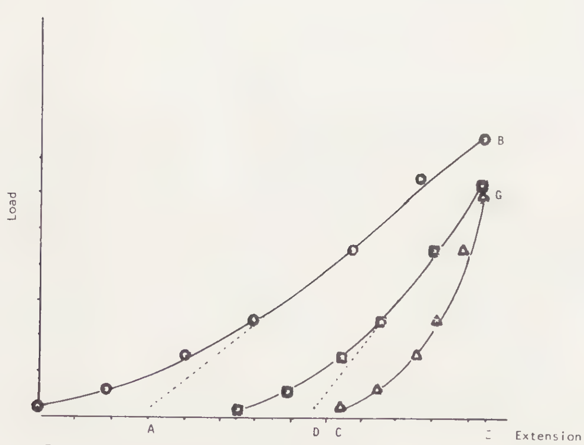


FIG. 5 Elastic properties of degreased wool

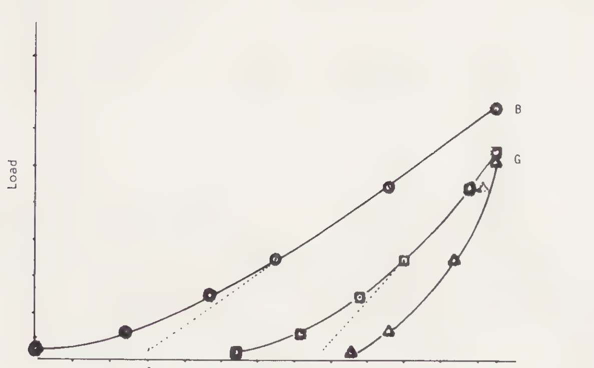


FIG. 6 Elastic properties of aged degreased wool

In testing the elastic properties of wool fibers, the variable which is of greatest consequence is the slope of the stress-strain diagram. For example, the slope is quite high in yarn made from combed long staple wool, but it is lower in yarn made of shorter fibers. It is possible to alter the slope of the stress-strain diagram with chemical treatments. For example, treatment with 1.5 Bé $NaHSO_3$, or 0.1 Normal HCl under certain experimental conditions reduces the slope, while under similar conditions steaming the yarn with aqueous ammonia causes the slope to increase.(13) Deviation from the established slope indicates changes in the physical or chemical properties of the fiber, but not necessarily a change of the tensile strength; fibers having identical tensile strength may have different stress-strain curve profiles. Testing elastic properties is on the whole a valuable tool for the assessment of fiber qualities.

It has to be remembered that elongation of the yarn is caused mainly by the slips of individual fibers it contains. To reduce this slippage and to improve the elastic properties in practice yarns are spun of 2-3 tightly twisted strands. The yarn specimen investigated in the present work is only of single strand and therefore the results indicate inferior properties than would be obtained in the finished product.

Plastic deformation is detrimental to the fiber and shortens its life expectency, all treatments to which the artifact is subjected should cause only so much stress that the resulting strain remains within the elastic limit. This should always be kept in mind when handling textile artifacts. Stretching should be avoided during washing or hanging on display.

By extrapolating the linear portion of the elongation curves, the points obtained (A and D) represent the beginning of the plastic elongation E represents in mm the 10% elongation to which the fiber was subjected.

The following equations were used for calculation:

Permanent deformation % $\frac{AD}{AE} \times 100$

Tensile strain recovery % $\frac{DE}{AE} \times 100$

Work recovery % is the area measured by planimeter

$$\frac{CGE}{ABE} \times 100$$

Table 1.

Elastic properties of natural, and degreased wool, before and after ageing.

	Permanent Deformation %	Tehsile strain recovery %	Work re- recovery %
Natural wool	35.48	64.52	25.78
Aged natural wool	38.55	61.44	26.44
Degreased wool	49.21	50.79	20.77
Aged degreased wool	49.47	50.53	20.55
Wool degreased at room temperature	37.96	62.04	22.57

The results given in Table 1 indicate that the elastic properties of the unaged natural wool deteriorated when subjected to degreasing in the Soxhlet apparatus. However, when wool was degreased at cold temperature Fig.7 no significant deterioration was observed. Whether

this last finding is due to incompleteness of degreasing or the increased sensitivity of degreased wool to elevated temperature cannot be decided. From conservation point of view the important conclusion is that dry-cleaning at elevated temperature should be avoided but probably at room temperature can be carried out without causing any harm.

Conclusions

1. Degreasing natural Corriedale wool fiber did not result in changes detectable by DSC and TMA.

2. Changes observable by DSC in natural and degreased wool due to aging by exposure to UV irradiation at high humidities were the same for natural and degreased wool.

3. Elastic properties of wool degreased at elevated temperature are inferior to natural wool.

4. The obtained results prove that without application of heat dry-cleaning is harmless to wool artifacts.

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Acknowledgements

I greatfully acknowledge the valuable cooperation of Mr. Herman Schultz National Research Council in carrying out some of the physical measurements.

I am much indebted to Mrs. Kay Kelland for the spinning of the Corriedale wool yarn.

Fig.7

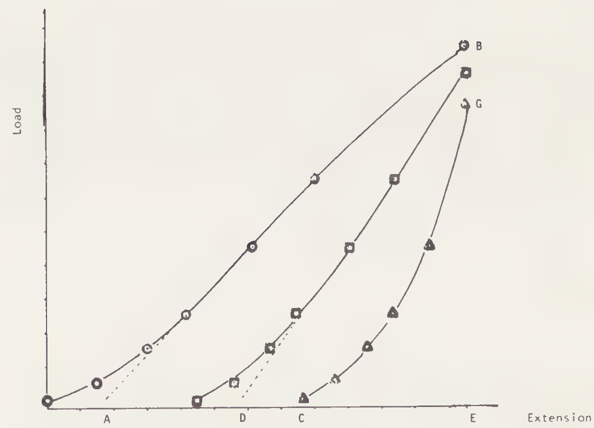

FIG. 7 Elastic properties of wool degreased cold

A 15TH CENTURY TAPESTRY OF NÜRNBERG. THE DIFFERENT STATE OF THE TWO HALVES OF ONE PIECE, WHICH HAD BEEN DIVIDED IN THE 19TH CENTURY. STATE OF PRESERVATION AND RESTORATION

Erika Weiland, textile restorer
Germanisches Nationalmuseum, Nürnberg

SUMMARY

A 15th century tapestry, manufactered in Nürnberg, had been divided in the 19th century. Both halves have survived, one in St. Lorenz Church in Nürnberg, the other one in a private American collection. The latter had got lost without trace. In 1973 it turned up at an art dealer's shop and was then acquired by the Germanisches Nationalmuseum. Thus the rare opportunity arose to compare the state of both parts before restoration.

I am sure the following statements are for many of you not new, but I think the fact that the two halves of the original piece were put together again to recreate a sublime work of art, justifies my speech on it.
In 1973 we textile restorers at the Germanisches Nationalmuseum happened to discover the right half of the tapestry at an art dealer's shop in Nürnberg. He showed us a photo of the tapestry, which was then in an American collection, and through this lucky circumstance we were able to bring the two halves together again.

The left half had been given to the Germanisches Nationalmuseum in 1926 as a permanent loan from the St. Laurence Church in Nürnberg. It was known as the "Fragment with Saints". The two pieces must have been cut apart some time in the 19th century, and no one had since heard of that missing half. When it became obvious, that the two pieces belonged together, the Germanisches Nationalmuseum made great and successful efforts to acquire the American half.
In the opinion of Dr. Leonie von Wilckens the tapestry has, in all probability, been woven by the nuns of the St. Kathrin's Cloistre in Nürnberg as an altar frontal for the church of the Domenican Friars. It shows on the right half, as centre of the complete piece, the Virgin with the child, who is presenting the engagement ring to St. Kathrin of Alexandria. The other saints, in the upper row from left to right are: Petrus Martyr, Vencencius Ferrer, Hortulana and Kathrin of Siena. In the lower row from left to right: beside the kneeling Kathrin of Alexandria, St. Barbara and St. Ursula.

On the left side, the Virgin is handing the scapular over to Reginaldus. Further you see in the upper row from right to left: St. Thomas Aquinus, St. Benedict and the two saints of the diocese St. Henry II and St. Kunigunde. In the lower row: the blessed Reginaldus, St. Dorothea and St. Agnes.

Dr. Leonie von Wilckens discovered, that the tapestry must have been manufactured between 1455 and 1461, due to the two facts visible on the American fragment:

(1) St. Vincencius Ferrer, in the centre of the uper row, who had been canonized 1455, but had not yet received a symbol when the tapestry was being made. The name on the scroll he is holding in his right hand has been embroidered after the tapestry had been finished.
(2) St. Kathrin of Siena, the furthest on the right hand side of the same row, is indicated as being not yet canonized by the different form of the halo she is wearing.

As soon as we laid the two fragments beside each other we saw the clear difference in their state of preservation. The colours of the Nürnberg fragment were much more brilliant, the white parts of the garments, made of linen, were brighter than in the other fragment. Looking more closely one can see that the material of the American piece has lost much of its volume. On examining the linen surface through the microscope the reason for the varnish-like discouloring becomes obvious. The linen has reached a certain degree of decay, the cuticles of the outer fibres having already disintegrated. Even gentle contact with a clean white cloth leaves a deposit of small brown fragments. Compared to the Nürnberg fragment, a brownish patina covers the American fragment. This is due to the differing conditiones under which the two pieces have been kept during their time apart. While the Nürnberg half only was hung on certain ecclesiastical days, either in the church or later in the museum, and then was stored again, the American half must have been kept under much less favourable conditions.

In 1964, on the conference of Textile Conservation in Delft, C.H. Giles, a scientist from the Royal College of Science and Technoloy, Glasgow, referred to the dangerous effect of light on textile fibres, as had other specialists before him. But Giles included the participation of other very important factors in this process, for instance: dye concentration, the physical state of the dye, when in the fibre, the nature of the fibre (in connection with the dye) the oxygen concentration which accelerates fading, and of course, humidity and temperature, which together intensify the damage, when uncontrolled. Giles pointed out, that in some cases the dye itself can act as an oxidation catalyst, as is obviously the case with cellulose fibres.
During the same congress A.H. Little from the Shirley Institute Manchester, mentioned besides other factors, the important roll of sulphur dioxide in accelerating the photochemical damage, especially on cellulose fibres.
Air pollution has meanwhile become so severe, that an aggravation of the problems in museums, especially in those that are situated right in the cities, is inevitable.

Since that conference 20 years have passed, and one is inclined to ask, what has changed since then? Many scientists have since researched in this field and frequently imparted their knowledge. But have we museum people learned from it?

The fading of colours on textiles is commonly known to be a result of the action of light. But what we do not see with the naked eye, is the decay of the fibres caused by the influence of light in combination with other factors. The small fragments of broken fibres on the glass table after having moved a brittle textile help us realise how far the destructon has already advanced. In those cases the damage is already severe, and we have to be very careful not to enlarge it by any treatment, whatsoever. A scientist, if possible specialized on textile chemistry, is actually the only person to decide what to do - or not to do.
In any case, we have tried to do our best, though we cannot say whether we have improved the condition of the American fragment by our treatment. Possibly our followers will find out one day!
First I would like to give you some technical details: The complete tapestry measures 260 cm in length and 85 cm in height. We counted 6 - 7 warps per cm.

The material used for the warps is linen. The weft is wool in different colours and linen for the white parts in the garments. Occasionally metal threads are used, i.e. gilt membrane strip around a linen core, as in the crown of the Virgin, in the girdles and clasps of some saints and the chalice of St. Barbara. The star on the forehead of St. Thomas Aquinas, as a more significant symbol, is woven in another kind of metal thread, a lamella on a silk core.

The treatment.

After careful safeguard measures as there are: covering the weak areas with cotton net and fixing the loose threads at the edges, both fragments were separately washed in a 5% solution of demineralized water and the detergent Nekanil W from BASF Ludwigshafen. We rinsed them three times and left them for about 10 minutes in the washing-table, that we brought into a sloping position, to allow the water to run out. Additionally we gently sponged the surface to accelerate the drying process. The washing procedure which we tried to keep as short as possible took about 50 minutes.
Having transferred each fragment onto a soft board by means of a melinex-sheet we smoothed out the piece and fixed it with rustless pins to let it dry in this position. The drying process was shortened by using air-driers. Afterwards we mounted each piece on a frame with rollers, where one obtains the even tension necessary for restauration.
The left fragment made no problems, the few missing parts were reconstructable and easy to reweave. Based on the traces of the original material we chose the matching colours for the weft and inserted it according to the original.
Where necessary, we replaced the original linen warps by cotton threads. We find cotton more suitable because it is much softer than linen and therefore safer to insert. For the reweaving we used wool of a relatively tight twisted quality which we dyed by means of synthetic dyes.

The American fragment required at every stage of restoration a treatment which differed from the corresponding procedures to the other fragment. It proved to be necessary to cover the whole tapestry with a net fabric to avoid any damage by handling during the washing process. The sponging had to be done very carefully, without any pressure. During the reweaving process the brittle linen warps had to be reinforced by fine cotton threads which were twisted around the original ones, so that the new weft-threads could be inserted without risk. The wool had to be dyed after new recipes, because all colours were quite different from those of the Nürnberg fragment.

Having finished the restoration work we lined both halves separately with a cotton fabric, which in first line is meant to have a supporting function. It is attached to the original by vertical stitch lines which are arranged in a certain way. The closeness of the lines depends on the state of the tapestry. As hanging appliance we sewed a velcro along the top edges of the two fragments and likewise to their inner edges were they adjoin. Both edges are fixed to the same hooked side of the velcro, thus allowing them to stay in position as an optical unit. By this arrangement the visitor is enabled to read the full message off the "complete" tapestry. We did avoid joining the two parts for two reasons:
(1) The left half is property of the St. Lorenz Church, the right one belongs to the Germanisches Nationalmuseum.

(2)Inserting all warps along the inner edges of both halves would have put too much weight on the weave.

The question of reweaving is more and more causing dissension.
We admit, that in many cases reweaving is either impossible or not recommendable.

But for the Nürnberg-tapestries, as they have been woven on linen warps, it has to be kept in mind that by completing the warps and inserting the weft the weave on the whole regains nearly its original stability.

We do not exclude that we would decide against reweaving in another case.

At present we are confronted with the bad condition of a 14th century tapestry from the Upper Rhine region. Its linen warps are very brittle, even more than those of our American fragment, which can partly be referred to the poorer quality of the original material. We are planning to attach this piece onto a supporting fabric, probably a woolen one, and not to hang it for display, but present it in a slightly sloping position.

In any case, every single piece demands its own special treatment and it is up to us to find the right way, always keeping in mind that the needs of an old textile must be decisive, but not our own personal ambitions.

Section 10

Stone

Matériaux pierreux

STUDY OF ACCELERATED WEATHERING OF LIMESTONES TREATED WITH AN ACRYLIC-SILICONE MIXTURE

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SUMMARY

Vicenza and Indiana limestones treated with an acrylic-silicone resin mixture were studied to determine the behaviour of the impregnant. The specimens were studied before treatment, after treatment, and after simulated aging in the laboratory. Water imbibition and the water absorption coefficient decrease after the application of the treatment. The open porosity decreases somewhat, especially for the larger pores, but does not change significantly even after aging. Scanning electron microscopy examination of the samples show that the mixture provides a fairly uniform coating on the stone particles. After aging the silicone resin (which is a prepolymerized methyl alkoxy silane) polymerizes further and forms a network that holds the covered particles together.

Introduction

Treatments for stone usually must provide two functions, a consolidating one, in the case where cohesion between the stone particles has decreased, and a protecting one, to prevent further damage. Rendering the stone surface and the pore structure hydrorepellent is one of the best protections against further damage [1].

The treatment discussed in this paper has proved efficient not only as a consolidant but also as a hydrorepellent [2,3,4,5] and has given good results in the treatment of extended surfaces of monuments [6,7,8].

The aim of this study was to examine the appearance of the resin *in situ* by scanning electron microscopy (SEM). The samples were examined before and after treatment, and also after simulated aging in the laboratory. The treatment was applied to stones that are not very susceptible to weathering so that the results obtained would not be obscured by changes in the stone due to the simulated aging process. The efficacy of the treatment was assessed by techniques such as porosity measurements and water imbibition tests.

Treatment

For this study the treatment was applied to two limestones: one from Vicenza, Italy, and the other from Indiana, USA. Both are clastic limestones: the first is fossiliferous and the second oolitic. Their structure is unhomogeneous and they differ with respect to compactness and porosity: Vicenza limestone has more of an open porosity than Indiana limestone which is more compact.

Samples of quarry stone from Vicenza (5 x 5 x 5 cm) and from Indiana (6 x 4.5 x 6 cm) were treated by capillary absorption with a mixture of 4.5 % w/v Paraloid B 72 and 3.5 % v/v Dri-Film 104 in organic solvents, mainly 1:1 acetone-1,1,1 trichloroethane. Due to its lower porosity, Indiana limestone needed more time than Vicenza limestone to be completely wetted. Both stones were left in the mixture for about 18 hours to insure the penetration of the resin throughout the samples.

After evaporation of the solvent the increase in weight for the samples of Vicenza stone was 1.5% and 0.6% for those of Indiana stone.

Experimental

The degree of water imbibition and the water absorption coefficient were determined by following the procedures recommended by RILEM 25 PEM [9] with some modifications [2]. The measurements were carried out before and after treatment.

The water imbibition was determined by 48 hour immersion at atmospheric pressure and the water absorbed expressed as percentage of the dry mass of the sample. The results are given in Table I.

Table I - Water absorption

	Water Imbibition mass %		Water Abs. Coeff. $(kg/m^2s^{0.5}) \times 10^3$	
	untreated	treated	untreated	treated
Vicenza	10.8	9.7	174.0	4.0
Indiana	5.8	5.1	72.5	2.3

The water absorption coefficient was calculated from the experimental curve obtained by measuring the water absorbed by capillary acrion (through the same face through which the mixture was absorbed) as a function of the square root of time. Data are from the initial slope of the curve. Results are reported in Table I.

After these determinations, the samples were halved, one half was used for porosity measurements and for SEM examination, and the other half was subjected to accelerated weathering. The weathering test was carried out by repeated cycles of sulphuric acid fog (4 hours) followed by drying in a climatic chamber (20 hours). Acid fog was obtained by means of a 0.02 M H_2SO_4 solution and about 1 ml of acid solution collected in each cycle on the horizontal face of the sample (the absorbing face). The climatic chamber was equipped with a 125 W UV lamp, with highest emission at 280-380 nm which was left on during the length of the exposure in the chamber at 50°C and 70% RH. The samples were subjected to 21 cycles.

Results

Total open porosity and distribution of the volume of the pores as a function of their radius was determined by means of a mercury porosimeter. The mean values of the porosity are given in Table II.

Table II - Porosity (vol %)

	untreated	treated	treated, aged
Vicenza	37.2	25.5	26.0
Indiana	22.6	19.7	20.3

The porosity of the untreated specimens are the mean of at least three determinations. In

the case of the treated and aged specimens, the mean was obtained from a larger number of determinations. To assess the homogeneity of the treatment, measurements were carried out on specimens taken at different distances from the absorbing face. The values obtained fall within the range of the results obtained due to the unhomogeneity of the stones themselves. In the case of the aged specimens the measurements were taken from the face exposed directly to the acid fog (absorbing face). The distribution of pore sizes for the Vicenza limestone are shown in Figure 1 and for the Indiana limestone in Figure 2. These are typical of the results obtained from all the measurements taken.

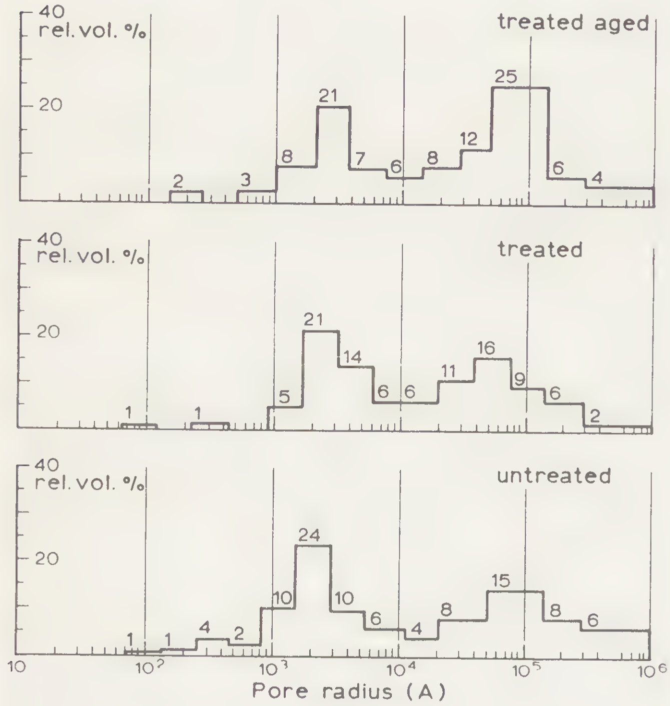

Figure 1. Relative pore volume distribution as a function of pore radius for Vicenza limestone.

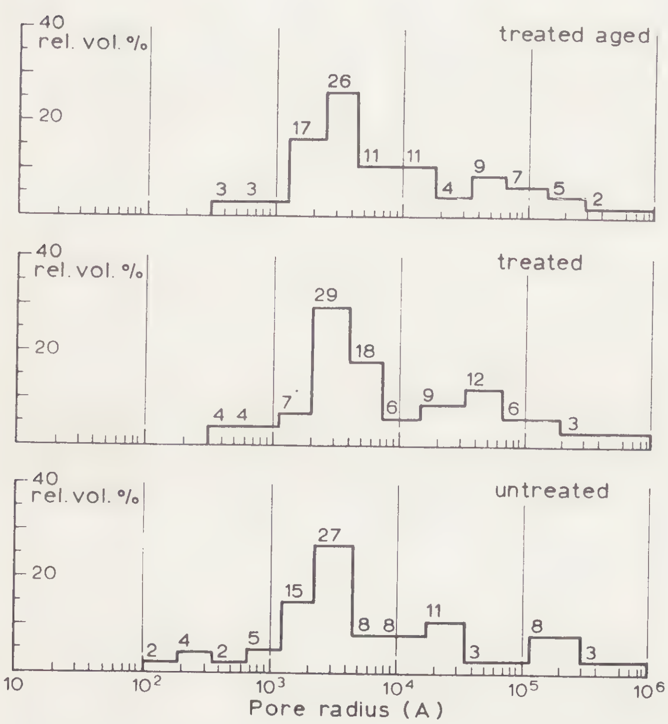

Figure 2. Relative pore volume distribution as a function of pore radius for Indiana limestone.

SEM examination was carried out on specimens from the external faces of the samples that were perpendicular to the absorbing face of the block. Both types of stone showed similar results due to the treatment and also due to the accelerated weathering process. The photomicrogaphs presented will be only of the Vicenza stone, but a similar set could be produced for the Indiana stone.

Through SEM examination of specimens from the interior of the samples it could be established that the penetration of the resin was fairly homogeneous throughout the stone [10]. The appearance of the exterior surface of the stone before and after treatment can be seen in Figures 3 and 4 respectively. Figure 5 shows the appearance of the stone and resin after the accelerated weathering process.

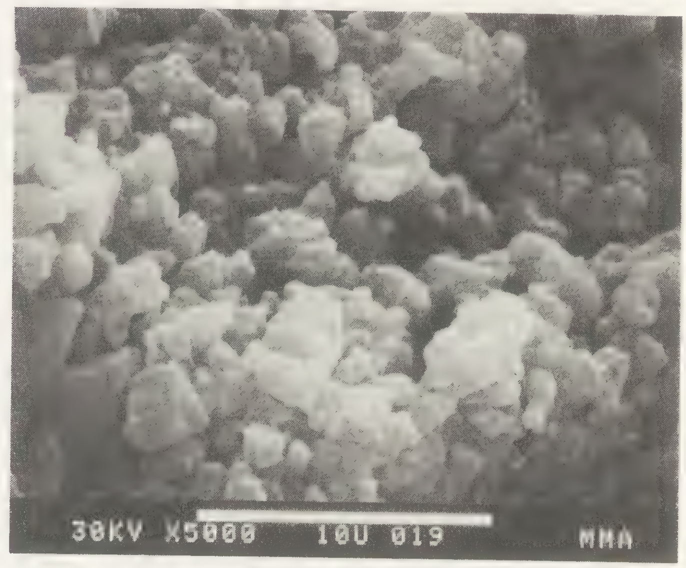

Figure 3. SEM photomicrograph of an external (sawed) surface of Vicenza limestone before the application of the treatment.

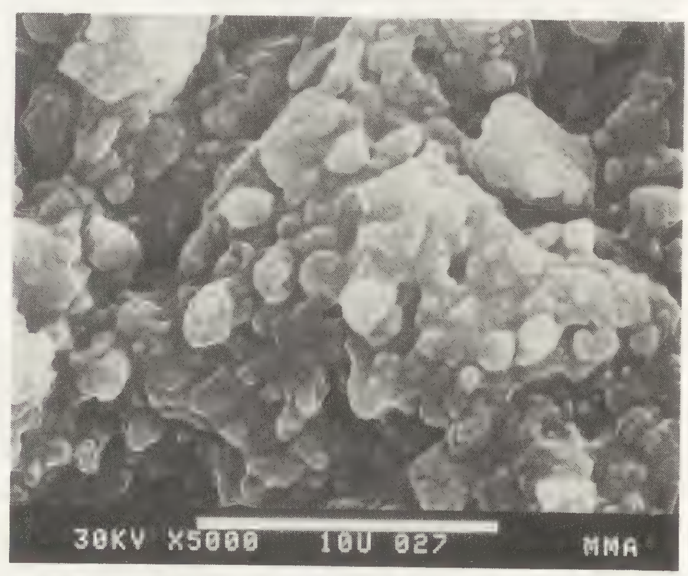

Figure 4. SEM photomicrograph of an external (sawed) surface of Vicenza limestone after treatment with the acrylic-silicone mixture. Note the homogeneous coating of the stone particles by the resin. The appearance of this film is characteristic of the Dri-Film 104 silicone resin.

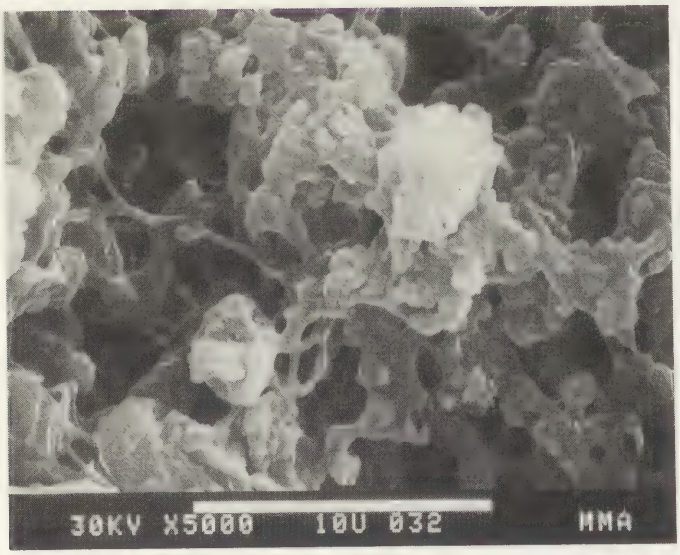

Figure 5. SEM photomicrograph of an external (sawed) surface of Vicenza limestone after treatment and after accelerated weathering. The larger pore space is due to the etching effect of the acid fog. Note that a network of resin has developed as a result of the weathering process. This type of network seems to be characteristic of in situ polymerization of silanes.

Discussion and Conclusions

The diminution of total porosity after the treatment and the fact that the relative distribution of pore sizes remains practically unchanged suggest that the distribution of the resin in the stone is fairly homogeneous. This conclusion can be substantiated by SEM examination [10]. Even though the total porosity is still high, the water absorption is reduced drastically. This can be explained by the hydrophobic nature of the Dri-Film 104. The appearance of this silicone resin in the stone is shown in Figure 4. The influence of the Paraloid B 72 in the mixture is not evident by SEM examination [10]. Dri-Film 104 deposits a film of the prepolymerized silicone resin as the solvent evaporates. The deposit on the outer faces is somewhat thicker than in the interior of the samples, which can be explained by the "carrying" effect of the solvent as it evaporates.

The effect of the accelerated weathering brings about a network formation in the resin which seems to be a characteristic of the in situ polymerization of silanes [10,11]. The appearance of the resin in the stone after the accelerated weathering is shown in Figure 5 which also shows in part the etching of the stone by the sulfuric acid fog. The change in appearance of the resin can be explained by the fact that Dri-Film 104 still has reactive alkoxy groups available for polymerization. The infrared spectrum of Dri-Film 104, shown in Figure 6, prove these to be mainly methoxy groups (850 cm^{-1}) [12]. Under the influence of the weathering agents, especially the acid fog, it is likely that these methoxy groups would hydrolyze and condense thus carrying further the polymerization reaction. Therefore it would appear to be that this silicone resin, whose first function is as a hydrorepellent, could also contribute towards the consolidation of the stone as the weathering process continues.

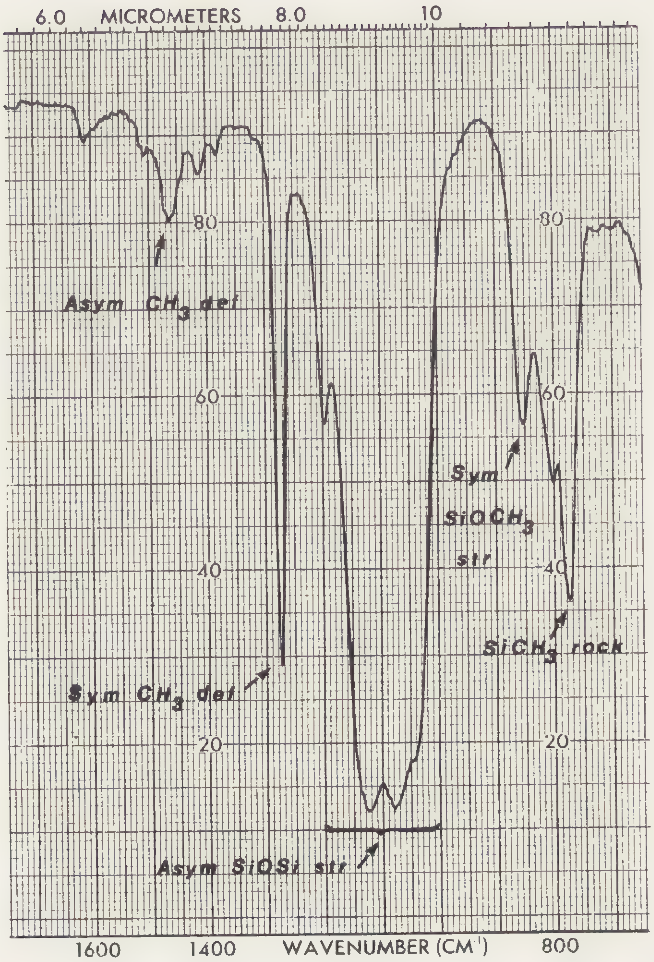

Figure 6. Detail of the infrared spectrum of the liquid Dri-Film 104.

Materials

Paraloid B 72, Röhm & Haas, is a methylacrylate ethylmethacrylate copolymer.

Dri-Film 104, General Electric, is a prepolymerized methyl alkoxy silane, presumably methyl trimethoxy silane, in solution.

Instrumentation

Fog Test Chamber: Weiss type S 400
Climatic Chamber: Weiss type T 240 + ZAB/20J
Porosimeter: Carlo Erba model 220 + Macropore Unit model 120

Acknowledgements

This study was partly supported by the National Museum Act Smithsonian Institution Grant No. FC-306156. Thanks are extended to Richard Sheryll for the help in SEM sample preparation and for the photographic reproduction of the SEM micrographs. Thanks are also due to Gregory Freund for the infrared spectrum of the Dri-Film 104.

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METHODS OF INVESTIGATION FOR MORTARS FROM THE ANCIENT AND EARLY - MEDIAEVAL BUILDINGS

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SUMMARY

Report as presented herein contains a discussion on the methods of testing samples from the relics of foundations and walls belonging to ancient and early-mediaeval buildings. Tests embrace macroscopic, chemical and quantitative /planimetric microscopy/ analyses to help determine composition and types of mortars and fillers used. Polarization microscopy, and in some cases also electron scanners, have been extremely helpful in identifying the structure, texture of mortars, degree of carbonization of lime mortars, as well as the type and character of particular components. Physical and mechanical tests have enabled the researchers to evaluate whether mortars prove to be in a good state of preservation or not. Differential thermal analysis has helped in telling dihydrous gypsum from the semihydrous one, calcium carbonate from dolomite, and in assessing the percentage of clayey minerals and organic substances. Investigations carried out with said methods on mortars from WISLICA /8/, WAWEL Castle of Cracow, KIJE, from ALEXANDRIA and from the Pyramid of Cheops have shown how diverse these mortars are; lime mortars, lime-and--gypsum mortars, gypsum mortars; and have also brought out to light high variability in the contents and in the type of particular filler ingredients.

1. INTRODUCTION

Investigation into mortars in the relics and in historical buildings from the ancient and early-mediaeval times call for the use of more complex methods. Said mortars stand out for their variety, both as regards the type of binder used as well as constituents of the filler. In Poland, a comprehensive programme of research on mortars was started in 1960 in connection with archaeological discoveries of the early-mediaeval historical relics found at WISLICA /1/. Excavation work continued over a time from 1959 to 1968 and was done by a Team for Research on the Polish Middle Ages, sponsored by the University of Warsaw and the Technical University of Warsaw. This led to the discovery of a 9th-century baptismal font with a clayey pedestal, and a single-nave church with an apse from the 10th century, and a burial chappel added later to it in the 11th century /2/. In the basement of a 14th-century Collegiate Church built of Tertiary limestone, with lime mortar used in it as binder, foundations and a fragment of walls belonging to two Romanesque Churches /3/ were revealed. A crypt with richly ornamented floor was discovered in the older Church. Discoveries made within the confines of the historic settlement included a number of relics belonging to four constructions from the turn of the 11th and 12th centuries. These embrace the so-called pallatium, a rotunda, another construction, and a rotunda with an octogen-plan apse and court flooring. Preliminary investigation into the WISLICA mortars by H.Jędrzejewska /5/ was intended to identify the type of binder used and to assess the ratio of the HCl-soluble matter to the insoluble residue. A more detailed research /8/, using a variety of testing methods, followed with regard to a large number of mortar samples collected from all historical relics at WISLICA, and also mortar samples from a Romanesque Church at KIJE /9/, and from the early-mediaeval relics of WAWEL /4/. Results of research concerning decorative floor and mortar samples from a Merovingian Tomb were published in 1965 /10/. Mortars from the Romanesque relics of structures discovered at GNIEZNO were tested by Brochwicz /11/. In 1980, tests were completed on mortar samples collected from the walls of a theatre, baths and cisterns of Alexandria, dating back to Roman times, as well as on mortar samples from the Pyramid of Cheops at GHIZA /12, 13/. An immense research material being an outcome of tests carried out on a variety of mortars has been found useful in laying down methods to be employed in the testing of mortars and in assessing their range of applicability.

2. TEST METHODS FOR MORTARS

Test methods as discussed hereinbelow were applied to the work on mortars.

2.1. Macroscopic Examination and an examination through a binocular magnifier have provided the possibility for a preliminary assessment of the type of mortar under investigation, its structure and state of preservation.

2.2. Determination of the HCl-Insoluble Matter is aimed at having the insoluble residue isolated from the mortar. Supplementary examination through a magnifying glass helps to assess preliminarily what the composition of a filler is.

2.3. Chemical Analysis included the procedure aimed at finding losses on incineration, moisture content, and the percentage of CaO and SiO_4^{2}. Findings served as a basis for calculating, as a percentage by weight, gypsum and calcium carbonate contents in the mortars. Fragments of limestones and gypsum happened to occur as filler in a number of samples liable to examination. For this reason, it was impossible to establish the actual content of binder in the samples by chemical methods, as reference made to test data often led to quite erroneous findings.

2.4. Planimetric Analysis in combination with the use of a polarization microscope and suitable attachment is good for quantitative assessment, as a percentage by volume, of the content of filler constituents, like quartz grains, gypsum crystals, limestone fragments, particles of ceramics and feldspars, debris, and even second-hand mortars when used, as well as tiny fragments of charcoal or remnants of cane not completely burnt and found in the Egyptian mortars /12/, as this material was used in Egypt for gypsum burning. The occurrence of voids was assessed, too. The difference gave the amount of binder having been used in the mortars.

2.5. Mineralogical Examination proceeded with the aid of a polarization microscope using a number of magnifications. This had as its

objective assessment of the structure and texture of mortars, type of binder, degree of its crystallization or carbonatization of the lime mortars, presence of limestones and other rocks as well as gypsum and quartz particles, their shape and size, degree of fineness, as well as small fragments of ceramics with quartz grains sticking in them, filler-binder bonds, presence of zones of the amorphous matter, like e.g. silica found in the ALEXANDRIA baths mortars /13/.

2.6. Electron Scanning Microscopy. In all those cases where the binder happens to be microcrystalline in its structure it will be scanning microscopy only to help evaluating to what extent a carbonate binder has gone carbonatized / $Ca/OH/_2$ is hexagonal and $CaCO_3$ trigonal / or to help reveal traces of the clayey matter or dolomite, or even some small quantities of carbonates, as it is likely to be in the case of the gypsum binders.

2.7. Thermo-Differential Analysis. Thermo--differential analysis has also been carried out to learn also composition of the mortar samples.

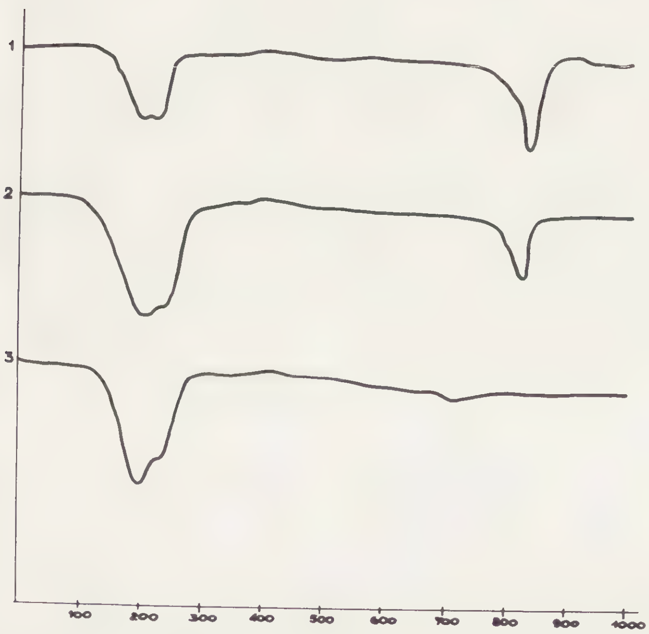

Fig.1. Thermogram curves of gypsum mortars from the grave plate and walls of a burial chappel added to a church from the 10th-century at WISLICA.

The shape of the thermogram curve depends on the constituents going into the make-up of a mortar. In gypsum mortars, a double endothermic effect with its minima at 205°C and 230°C as a result of gypsum dehydration takes place. The area of the effect depends on the amount of gypsum included in the mortar. Endothermic effect with its maximum at 390°C is related to the gypsum-anhydrite restructuring process. When carbonates are there, the mortar will be liable to endothermic effect at temperatures exceeding 800°C as a result of the dissociating calcium carbonate /pure calcium carbonate dissociates at about 950°C/. The less carbonates the smaller will be area of the effect, with the latter's position shifting towards lower temperatures. Endothermic effect due to dissociation of carbonate in lime mortars materializes at about 800°C. At a temperature of about 570°C there follows the process of polymorphic transformation of quartz and an endothermic effect takes place; the extent of this effect being dependent on the amount of quartz present in the mortar. A weak,washed-out, endothermic effect with its minimum at 130°C is connected with the removal of water adsorbed. An endothermic effect is also possible at 740°C, when the sample contains clayey additives or when dolomite is present in it in small quantities. Mortar samples from WAWEL, for instance, lacked the effect due to the dissociation of carbonates. The KIJE sample, on the other hand, featured endothermic effect at 220°C and an exothermic effect at 380°C, which is a proof that this is semihydrous gypsum, as also the dehydration is a single effect. Endothermic effect at 750°C points to a small amount of calcium carbonate. Endothermic inflexion at 650°C may be related to small admixture of silty minerals. In no one of the mortar samples liable to investigation endothermic effects corresponding to the decomposition of organic matter could have been traced, as the amount of carbon particles in the mortars was very small indeed.

2.8. Physical Examination. Physical characteristics to be verified in the case of mortars include density, apparent density and absorptivity /imbibability/, as they prove very useful in evaluating some very important qualities, such as porosity /void ratio/, tightness, and percentage of the totally enclosed voids. Analysing such features, we are in a position to assess how the mortars have withstood the time and to evaluate the rate of wear they have undergone as a result of, say, leaching of the binder or gypsum filler.

2.9. Mechanical Tests. Whenever larger samples, as e.g. those coming from the WISLICA Court flooring /7/, are made available, and in the case of some other mortar samples /8/, compression and abrasion tests could have been made. High strength of the material as proved in some of the cases did not yield to the qualities of the estrich gypsum mortars according to present-day technological specifications. Abrasion resistance in the uppermost layer of the Court flooring acc. to the Boehms grinding wheel test was very good as this gypsum mortar had much sand in it, which is a proof for a deliberate use of the additive. When samples are very small, new mortars can be produced according to the earlier-learnt specification of the ancient mortar to evaluate their mechanical properties /7/.

2.10. Other Data. Brochwicz /11/ embarked on a chromatographic programme to reveal the presence of organic matter. But, even using this technique, he failed in his attempt. He tried to plot also grain-size distribution curves for sand, after the separation of filler from lime mortars.

3. S U M M A R Y

The work on ancient mortars has shown that nothing but only a complex research is likely to lead to an unmistakable assessment of the type, composition, and the state of preservation of mortars. Chemical analysis and an estimation of the insoluble matter can be regarded as introductory only. Physical and mechanical characteristics allow the researchers to judge a mortar from the point of view of its usefulness in the engineering applications. Microscopic examination, on the other hand, furnishes detailed information about binders used in the mortars, their actual state of preservation, kind of filler employed, and about additives supposed to improve mortar properties. Thermal analysis is an extra source of information to reveal the presence, if any, of such additives as clayey and organic matter, etc.

Carbon inclusions in the mortars under examination were so negligible that they could not give any thermal effect.

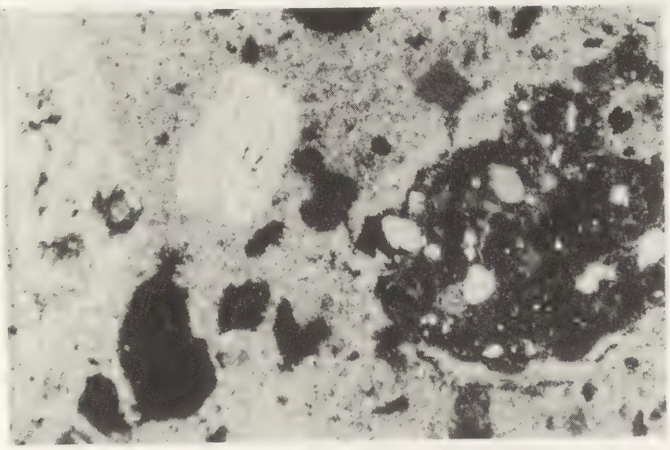

Fig.2. Microphoto of a gypsum mortar from the walls of a burriel chappel at WISLICA. As a filler there are the grains of gypsum, quartz and ceramica with quartz grains sticking in them.

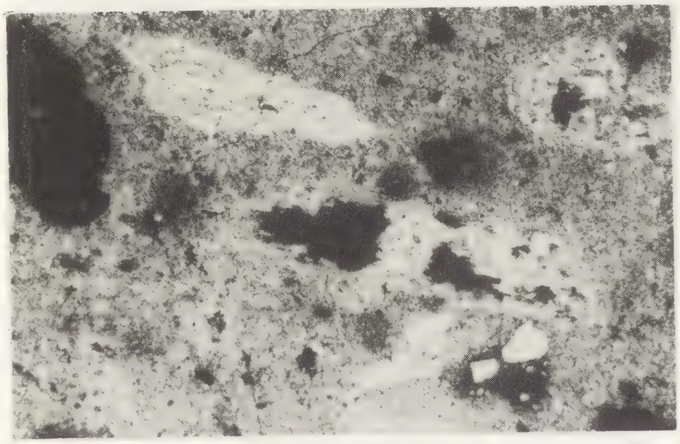

Fig.3. Microphoto of a gypsum mortar from the First Romanesque Church at WISLICA. As a filler we see the grains of quartz, ceramica and destroyed fibrous gypsum.

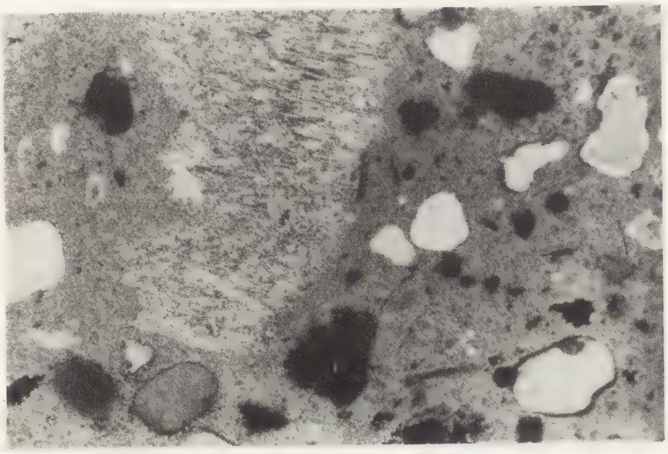

Fig.4. Microphoto of gypsum mortar from a Rotunda with an octogen plan at WISLICA. As a filler there are many grains of quartz, fibrous gypsum and fragments of ceramica and charcoal.

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EVALUATION OF MORTARS FOR USE IN CONSERVATION FROM THE STANDPOINT OF THE RELEASE OF SOLUBLE SALTS

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SUMMARY

On the basis of some preliminary tests, an experimental procedure has been established in order to extract and evaluate quantitatively the amount of water-soluble salts released by mortars and injection grouts, commonly used in conservation works on ancient masonry walls. Out of the many chemical parameters measured, the most significant for the characterization of mortars proved to be the specific conductivity of the solutions and the concentration of Ca^{++}, Na^{+} and K^{+}. The results concerning five different groups of mortars and injection grouts are given: by using the experimental procedure suggested, it is possible to discriminate among different commercial products and to evaluate their "harmfulness" due to water-soluble salts.

1. Introduction

One of the main problems in the use of a new mortar or injection grout on ancient masonry walls is the release of soluble salts and their eventual migration towards the painted external surface, or towards stuccoes and other decorative elements.

The disruptive and disfiguring action of soluble salts is well known and for this reason it is essential to test any mortar in advance, measuring the amount and, if possible, the chemical nature of the soluble salts that can be released when the mortar is in contact with water.

To date, there is no standardized method available for testing mortars for conservation from the standpoint of their content of water-soluble salts; the aim of our work is to establish an experimental methodology, reliable and relatively uncomplicated, which permits such an evaluation.

In a first step of the research we attempted to discover the best experimental conditions to solubilize salts, in order to make them measurable. We checked the influence of three factors: grain size of the sample, ratio sample/water and time of extraction.

At the same time we measured many different parameters of the solution obtained (pH, specific conductivity, concentration of Ca^{++}, Mg^{++}, NH_4^{+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{--}) and we were able to identify the most significant among them (1).

The experimental methodology established in this first phase was applied to many different mortars and grouts prepared by an ICCROM research team (2, 3).

This second phase allowed us to evaluate whether our methodology was reliable and useful in distinguishing among different products and, at the same time, in characterizing those products on the basis of their salt release.

2. Experimental part

For the sake of brevity, we cannot describe here the results obtained when studying the factors that influence the extraction conditions; these were already given in detail in a previous report (1).

The conditions which proved to be the most satisfactory are as follows:

amount of sample	= 5,00 g
granulometry of sample	≦ 106 µm (Sieve ASTM Series E11-70 Mesh 140)
amount of deionized water	= 200,00 g
time of extraction (on a shaking table)	= 7 days

The ground and sieved samples are put in a polyethylene jar with a large screw plug(Ø 35 mm), capacity = 250 ml. This type of container permits better shaking efficiency than the traditional glass flasks. At the end of the extraction, the solutions are filtered and their volume brought to 250 ml.

The most significant physical and chemical parameters, out of all those measured, were found to be pH, specific conductivity, concentration of Ca^{++}, Na^{+} and K^{+}. The amount of Ca^{++}, indeed, seems to have the greatest influence on pH and specific conductivity; Na^{+} and K^{+} ions, on the other hand, give rise to very soluble and dangerous salts, and therefore it is important to know their concentration, even though it is generally lower than the Ca^{++} concentration.

The pH measures were performed by using a Radiometer 27 Phmeter, equipped with a glass electrode; the specific conductivity by a Philips PW9501 conductivity meter; Ca^{++} concentration was measured colorimetrically by an Autoanalyzer Technicon II; Na^{+} and K^{+} by flame photometer Elvi 655.

The above methodology was used to characterize five groups of different mortars and injection grouts, prepared by the above-mentioned ICCROM research team. They tested those mixtures from the standpoint of mechanical and other physical properties and applied them in many field experiments (2,3).

The samples of the five groups are described in table 1. Some further details about raw materials and preparation of samples are given in the ICCROM reports (2,3).

The samples of group I represent traditional mortars, commonly used by building contractors.

The samples of group II are mortars of hydraulic lime and crushed brick to which three different products were added with the aim of reducing the amount of soluble Ca^{++}. In this case only pH, specific conductivity, and concentration of Ca^{++} were measured in order to evaluate the effect of the three products.

In group III we have grouts obtained from different binders without any filler.

Finally, the influence of different fillers on the salt release of different binders is given by the analysis of groups IV and V.

The experimental results are reported in tables 2 - 6; two samples of each type of mortar were extracted and analyzed; the results reported are always the mean of two values.

3. Discussion

The experimental results clearly show that it is possible to differentiate the different samples from the standpoint of soluble salt release by applying the proposed methodology.

It is also possible to establish a ranking order of the traditional mortars of group I as follows: B, C, A, D (see table II).

The high content of soluble substances of mixture D (Lime/Sand) is mainly due to the presence of Ca^{++}, as some not reacted calcium hydroxide is still present, even when the sample has had a year's seasoning before the test (X-Ray Diffraction analysis confirms this hypothesis).

The addition of pozzolanic compounds which can react with lime (sample B), sharply reduces the release of soluble Ca^{++}; a similar, but weaker, effect is produced by small amounts of cement.

Samples E, F and G (group II) are compared in table 3 with samples P and Q, similar in composition but without any admixture. All three products improve the release of calcium; ammonium phosphate, however, is much more effective than ammonium carbonate and oxalic acid.

In group III (see table 4), sample I (hydraulic lime UNICEM) has the lowest specific conductivity and,

correspondingly, one of the lowest contents of soluble Ca^{++}; on the other hand, sample L (hydraulic lime Lafarge) is the best from the standpoint of Na^{+} and K^{+}; in this case the high amount of soluble Ca^{++} is surely due to the presence of not reacted $Ca(OH)_2$; in fact Portlandite was one of the major crystalline components of the product, before curing, as shown by X-Ray Diffraction analysis.

Interesting results are given by the two last groups where the effect of different fillers was studied by adding them to the hydraulic lime Lafarge (table 5) and to two types of cement (table 6): in every case the addition of the fillers reduced the amount of soluble Ca^{++}.

Pozzolana proved to be the most effective, in this respect, when added to the hydraulic lime but, at the same time, it produces an increase of alkaline ions expecially K^{+}. In comparing samples R and S it is impossible, at least for the moment, to understand why the increase in the K^{+} percentage is lower where the amount of Pozzolana is higher (sample S).

This effect of pozzolana, however, is perfectly in agreement with the results given by sample B.

A good effect is also obtained by the addition of crushed brick, particularly at the higher ratio 1:1 ; again in group V, sample T, containing Dicalite as filler, gives interesting results: this diatomaceous earth significantly reduces the amount of Ca^{++} and, at the same time, does not produce any increase of $Na^{+} + K^{+}$.

As far as cements are concerned (table 6), the positive effect of the fillers is confirmed; in particular mixture W (pozzolanic cement/crushed brick = 1:1) shows an interesting decrease of all the ions measured.

4. Conclusions

As already stated, the proposed methodology of extraction of water soluble salts is suitable for revealing differences between similar mortars and in the case of mixtures obtained from different binders.

Moreover, this methodology is rather easy and rapid. A further simplification could be obtained by measuring only the specific conductivity, because the correlation between this parameter and the total amount of the measured ions is rather good: the regression curve (calculated on the results of all the samples except E, F and G) has a correlation coefficient r=0,95 and is given by:

$$Y(\mu S/cm) = -377 + 5{,}9\ X(\mu equiv/g) \qquad \text{(fig.1)}$$

As a consequence, the specific conductivity of the solution could be considered sufficient, in a first approximation, to reveal the "risk" of a certain mortar from the standpoint of the soluble salts it can release.

Of course, the direct measurement of Ca^{++}, Na^{+} and K^{+} allows a better evaluation of this risk, with regard to any particular application.

It is of course desiderable that, when dealing with monuments and ancient masonry, the release of water soluble salts be as low as possible, but at the same time, one is sometimes forced to choose products having good workability, good mechanical resistance and producing an acceptably low amount of soluble salts.

The experimental results show that, generally, in the binders available to date, when the Ca^{++} content is high, the Na^{+} and K^{+} percentage is low and vice-versa.

In the first case (high Ca^{++} value) the mortar will provoke, in the course of time, the formation of incrustations of insoluble $CaCO_3$; this could be acceptable in the case of light coloured walls without any painted decoration.

When the mortar is to be applied near a fresco painting or, more generally, on a decorated wall it is obligatory to use a mortar with a low content of soluble Ca^{++}, chosen from among the products with the minimum amount of alkaline ions.

As far as the experimental methodology is concerned, we think that the present work could be a first step, a suggestion, towards the definition of a standard method of the evaluation of mortars and grouts.

In this respect it is worth remembering that, at the moment, it is impossible to establish an "acceptability limit", i.e. the maximum amount of soluble salts that can be tolerated in a mortar for use in conservation.

However, in a first attempt, one could refer to the values of a traditional mortar obtained by adding some pozzolana to lime. This type of mixture, indeed, has been in use since the antiquity and generally has not caused damage related to soluble salts (4).

If we consider the values of sample B, corrected to take into account the "dilution" due to the high amount of sand (75%), and if we double these results in order to avoid values that are too low and unrealistic, we obtain the following tentative limits:

Specific conductivity = 1000 μS/cm
Ca^{++} = 0,40 %
Na^{+} + K^{+} = 0,25 %

Among all the mortars and grouts analyzed, only three could be accepted on this basis:

Sample B : lime/pozzolana/sand = 4/2/10
Sample I : hydraulic lime UNICEM
Sample T : hydraulic lime Lafarge/Dicalite = 1/1

Of course it will be necessary to carry out further experiments to find out a direct correlation between the release of soluble salts and the damage produced by the mortar, also in relationship to the characteristics of porosity and permeability of the wall.

Acknowledgements

The authors wish to thank Mr. S.Diana and Mr. O.Basiricò for their valuable help in carrying out the measurement of many of the parameters, and Mrs. C.Rockwell for checking the english text.

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fig.1

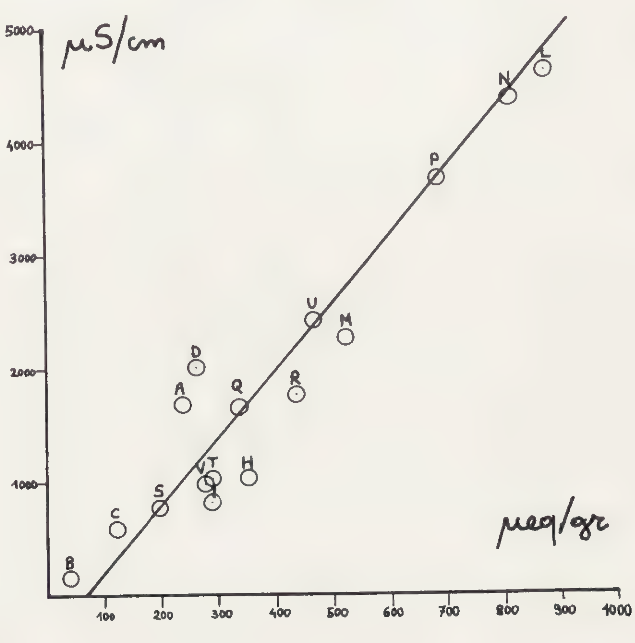

TABLE 1 : Description of the samples.

GROUP	SAMPLE	MORTAR AND INJECTION GROUTINGS
I	A	Portland Cement (Italcementi) : sand = 1:1 (by vol.)
	B	Lime : pozzolana : sand = 4:2:10 (by vol.)
	C	Lime : Portland Cement (Italcementi) : sand = 3:1:12 (by vol.)
	D	Lime : sand = 1:3 (by vol.)
II	E	Hydraulic Lime(Chaux Blanche-Lafarge) : crushed brick = 1:1 (by vol.) + $(NH_4)\ HCO_3$ (30% by wgt)
	F	Hydraulic Lime(Chaux Blanche-Lafarge) : crushed brick = 1:1 (by vol.) + $(NH_4)_2HPO_4$ (30% by wgt)
	G	Hydraulic Lime(Chaux Blanche-Lafarge) : crushed brick = 1:1 (by vol.) + $(COOH)_2$ (50% by weight)
III	H	Hydraulic Lime (Italcementi)
	I	Hydraulic Lime (UNICEM)
	L	Hydraulic Lime (Chaux Blanche-Lafarge)
	M	Pozzolanic Cement 325 (Colacem)
	N	White Cement "Aquila Bianca" (Italcementi)
	O	Two components injection Cement "Damp and Dry"
IV	P	Hydraulic Lime(Chaux Blanche-Lafarge) : crushed brick = 2:1 (by vol.)
	Q	Hydraulic Lime(Chaux Blanche-Lafarge) : crushed brick = 1:1 (by vol.)
	R	Hydraulic Lime(Chaux Blanche-Lafarge) : pozzolana = 2:1 (by vol.)
	S	Hydraulic Lime(Chaux Blanche-Lafarge) : pozzolana = 1:1 (by vol.)
	T	Hydraulic Lime(Chaux Blanche-Lafarge) : Dicalite = 1:1 (by vol.)
V	U	White Cement "Aquila Bianca" (Italcementi) : Dicalite = 2:1 (by vol.)
	V	Pozzolanic Cement 325 (Colacem) : crushed brick = 1:1 (by vol.)

N.B. - Pozzolana is "Pozzolana superventilata", manufactured by "Pozzolane di Salone, M.Testa", Rome, Italy
- Dicalite is a diatomaceous earth, manufactured by "Diatom", Castiglione Teverina, Italy
- Sand is "Standard Sand for Cement Testing", Supplier : S.I.S.A., Torre del Lago, Italy
- 0,1% (by weight) of Sodium Gluconate was added as fluidizer to samples H-V.

TABLE 2 : Traditional mortars

Sample	pH	specific conductivity µS/cm	Ca%	Na%	K%	Na+K%
A	11,1	1675	0,45	0,01	0,03	0,04
B	9,3	150	0,06	0,01	0,03	0,04
C	10,4	575	0,23	0,01	0,02	0,03
D	11,3	2000	0,52	0,01	0,01	0,02

TABLE 3 : Groutings based on Hydraulic Lime/crushed brick, with admixture

Sample	pH	specific conductivity µS/cm	Ca%
E	11,5	1140	0,42
F	10,8	415	0,14
G	11,3	1350	0,40
P	10,5	3650	1,22
Q	10,4	1650	0,46

TABLE 4 : Binders without filler

Sample	pH	specific conductivity µS/cm	Ca%	Na%	K%	Na+K%
H	10,4	1025	0,37	0,06	0,57	0,63
I	9,8	800	0,41	0,09	0,19	0,28
L	11,2	4650	1,69	0,02	0,11	0,13
M	10,7	2250	0,40	0,22	0,90	1,12
N	11,0	4350	1,48	0,04	0,23	0,27
O	11,5	5200	1,35	0,24	0,03	0,27

TABLE 5 : Groutings based on Hydraulic Lime Lafarge and different fillers

Sample	pH	specific conductivity µS/cm	Ca%	Na%	K%	Na+K%
L	11,2	4650	1,69	0,02	0,11	0,13
P	10,5	3650	1,22	0,07	0,20	0,27
Q	10,4	1650	0,46	0,10	0,24	0,34
R	10,6	1750	0,42	0,12	0,69	0,81
S	10,4	750	0,11	0,09	0,42	0,51
T	10,8	1000	0,50	0,05	0,08	0,13

TABLE 6 : Groutings based on cements and different fillers

Sample	pH	specific conductivity µS/cm	Ca%	Na%	K%	Na+K%
N	11,0	4350	1,48	0,04	0,23	0,27
U	11,0	2400	0,80	0,04	0,21	0,25
M	10,7	2250	0,40	0,22	0,90	1,12
V	10,6	975	0,13	0,16	0,56	0,72

ON THE WORK WITH ANCIENT RUINED SCULPTURES IN THE STATE HERMITAGE

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Summary

The present-day restorer, besides his main task - the conservation of the monument's material - , faces some problems of no less importance. These are the preservation and, when necessary, restoration of the artistic and expositional value of works of art. The results of the theoretical studies and some examples of the practical realization of the theoretical principles are given.

In the State Hermitage, at different times, there was carried out some work on recompositi tion of ancient marble sculpture. This work began as early as XIX century when the development of art criticism led to the understanding of the numerous errors made by sculptors of the past centuries, who, as a rule, reconstructed the lost fragments of ancient sculpture arbitrarily. Then a decision was taken in some museums to remove the reconstructions misrepresenting the plot or spoiling the general style of the objects. In I850, in the Hermitage Museum of Antiquities, there were taken away both arms from the Venus of Taurida wrongly reconstructed in XVIII century by a French sculptor Gnaccarini in Rome.

The ancient sculpture collection of the State Hermitage was formed in XIX century. Most of the sculptures were received from private collections (L.Brown, Campana and others) and were already restored, that is, they were assembled from the original parts and from fragments reconstructed in XVIII - XIX centuries in Italy. At the turn of XX century the museum workers studied the added fragments on different sculptures. As a result of this work which was carried out under the guidance of professor Waldgauer, in the 20-30s the antique heads were detached from the torsos wrongly jointed to them, and were put on separate supports. For example, the head belonging to the statue of Dionysus was removed from the statual portrayal of Erinye and put on exhibit separately.Removed were also the reconstruction of the hands with the olive branch. (She was intended to hold an object having a contrary meaning to that of the olive branch which is a symbol of peace, that is, some minister of vengeance). Similar operations were performed with the statues of Athena, Socrates,Demosthenes, Hermes and some other sculptures with wrongly reconstructed fragments.

Some antique fragments, however, were considered to be reconstructed and jointed well, and they are still on exhibition. One of these is the statue of Dionyses assembled in XVIII century from several fragments both taken from different antique sculptures and made of new reconstructions. The statuette of Silen was reconstructed in marble with great skill. Judging from some indication, it was restored in the studio of a well-known Italian sculptor-restorer Bartholomeo Cavaceppi.

For some years past, in the State Hermitage some more antique sculptures wrongly restored by the sculptors of the past centuries have undergone some studies and recomposition from the point of view of up to date principles of exposition and restoration. This kind of work is being carried out by ancient art specialists together with restorers. In the course of the studies and the restoration work, the contaminations and the tone and putty layers, concealing the lines between the original parts and the added fragments, are removed from the sculpture surface, making the lines easily discernable.

Some additions were dismantled as the restoration putty got degraded and it had to be changed. In the past centuries the wax-colophony melt or plaster of Paris were used for the restoration of stone sculpture. New details, as a rule, were prepared from stone. When the additional parts were being jointed with the ofiginal object, a site or a "nest", a hole for fixing it, was prepared. To increase the stability of the jointing, some holes were drilled where some pintles or cramps were put fixing them with the same glue putty, plaster or lead. The glue seams were filled with some putty made of marble meal or gypsum with the wax-colophony melt.

The glues and putty from natural substances used for restoration in the past in the course of ageing become brittle, they lose their adhesive properties. The joints of parts glued together become unstable, the fragments happen to fall off or are kept in their places only by metallic fastenings. The iron framework parts of the old restoration are also not always reliable, as in unfavourable conditions they are subjected to corrosion and lose their stability. It is not seldom that the restorers have to give first aid to objects exhibited in the museum and glue up the fragments getting detached.

After the surface is cleaned from contaminations and restoration tonings, the glue seams and the holes filled with the darkened restoration putty become visible. They break the sculpture forms with dark stripes, injuring the impression integrity. That is why some work is being carried out at the Hermitage exposition currently on cleaning the seams on some marble sculptures and substituting the putty imitating marble and based on the lightstable polymer adhesives for the wax-colophony putty. Besides, some insertions from transparent marble which due to the darkened glue look like dark spots have to be also removed.

To detach the parts glued with wax-colophony putty, the stone is heated to 60-80°C in the glued places; or the gluing mass is solved by applying a compress wetted in a solvent mixture (alcohol - acetone-turpentine or alcohol-methyl cellosolve in equal parts). The fragments disjointed, the wax-colophony mass, made soft by heating or by solution, is removed with the help of a heated metallic palette-knife. The remnants of the mass are washed away with a swab wetted in the solvents. After the added fragment is cleaned from old restoration glues, it is glued anew with one of the present-day polymer glues adopted for use in the restoration of stone, if the fragment was considered worth remaining in the antique original.

The question of removing or preserving the added fragments is decided by a council of specialists (art critics, historians, artists, restorers). As a rule, it is a debatable question, and two main positions are represented most of all:

- from the point of view of archaeology and history the ancient work must be exposed delivering it from everything introduced to it in the course of its life in order to facilitate the perception of the object.

- from the point of view of the theory and history of art and the museum science a work of art cannot be looked at abstractly, out of touch with the social aspect of the art evolution, taking into account the fact that the restorative additions are a factor of ancient art interpretation in different periods of the artistic development of mankind.

A decision is taken on every particular case considering the peculiarities of the work, the exposition conditions, the possibilities of the restorer, traditions, and the museum aims.

To take an example, from the marble torso of Aphrodite (work of a Roman master 2nd cent.) it was decided to take off some crudelly added fragments on the breast and abdomen. After the fragments were removed, there remained in their places some cuts from the restoration work and the holes for pintles, which prevented normal perception of the sculptural forms. It was necessary to take some measures to restore the artistic expressiveness and the expositional value of the work. With this end in view, some putty, imitating marble, prepared on some polymer basis was put on the section surfaces and treated in imitation of a natural fracture. This technique makes it possible to counteract the restoration damage without causing any additional destructions of the material of the original object. And in case of a new decision to derestore the object, the mass imitating the decayed marble will be easy to remove with the help of a compress and some solvents.

A similar method was used in restoring the statue of the priestess Isida (Rome, 2nd cent.). In the past the torso of this statue was jointed with a head of an archaic type made in imitation of the VI century Greek original. In the I920s the head and the reconstructed arms were removed from the statue. There remained an insertion with a round hinge groove to joint the head with the torso and some marble and plaster insertions. They hindered the perception of the work of art in the right way, and it was decided to remove them. The groove was treated with a chisel in imitation of a fracture, as it was not original fragment; and the surfaces exposed after removing the insertions were treated so as to make them look like "fractures" with the help of some polymer putty as in the case above.

When restoring the statue of a Roman Woman Sitting in an Armchair (Rome, II cent.), the restorers faced an unusual problem. In the course of the examination it turned out that it was assembled from two marble fragments taken from different antique statues (the upper part up to the waist, and the legs from the ankles up to the thighs), as well as from a considerable part of gypsum fillings (the middle part of the statue, the armchair and a part of the garment folds including). The statue appears to have been created in the restoration studio attached to the Campana museum in Rome. To conceal the style discord of the upper part, the sculptor covered the folds, which represented thin cloth with great skill, with new folds in the style of the upper part. When those folds were removed, and the antique fragment revealed, this discord became evident, and the question arose whether the statue should be dismantled and the fragments exhibited separately, or to leave the composition as it was as a rare sample illustrating the history of restoration and as an example of the interpretation of ancient sculpture in XIX century. The latter variant was adopted by the council of specialists.

Currently, the reconstruction of lost parts on ancient sculpture takes place only in exceptional cases when there is some need and convincing scientific sources indicative of the original composition, the artist's intention and style. Descriptions, engravings, photos, moulds, as well as similar sculpture compositions of both monumental and easel sculpture, reliefs, small plastic bronzes, glyptics, numismatics and others may serve as sources for the reconstruction work. That is why, the reconstruction is preceded by the study of the sources and by the research work of the sculptor. The drafts for the losses to be reconstructed may be made graphically (drawing, photo) or plastically as a reduction copy, or plaster of Paris mould.

In some cases, however, especially when the losses are intermediate, there is a necesity for a partial or full reconstruction of the lost part with the aim to restore the expositional value of the fragmented sculpture by analogy. It can be performed conditionally without the details being worked out, with some differences from the original parts. So far as it is known to us, different museums apply different techniques in work like this. They are based on a partial compensation of the lost shape (volume), texture and colour. Different techniques can be used in different cases resulting in restoration additions with:

a) similar, generalized or simplified form;

b) similar, differing, strongly differing texture;

c) similar, neutral, differing colour.

In the practical work at our museum there were some examples of such conditional compensation of losses. For example, several fragments of a terra-cotta statuette "Reposing Heracles" found in the archaeological excavations of ancient Olvia were jointed by modelling the original volume of the part lost with the help of raw clay and polymer adhesive. This conditional compensation united the preserved fragments, reconstructing only the silhouette and the total mass of the lost sculptural forms, differing in texture and colour from the original parts. The conditional composition is made by analogy with similar portrayals of the same personage.

In another case, the lost fragments of a Greek oinochoye, VI century A.D., signed by master Kharin, were reconstructed with a putty of gypsum with some pigments and a polymer adhesive which imitated rather faithfully a crock of redfigure ceramics, but slightly differing in colour and texture. Besides, the painting design and small modelled details (for example, the hair locks) were not reconstructed.

Several fragments of a Byzantine stone icon with the portrayal of Christ were assembled on a toned plaster plate with a conditional tracing of the lost middle part of the

picture made by analogy with other icons of that time and reproducing the same subject. A compensation like this makes it easier to feel the meaning of the fragments and the spirit of the work's lost parts.

In the marble statue of Dionysus from Panticapeum we reconstructed the loss of a leg. The statue was found with some ruined fragments. Lost was a part of the leg (left shin). While assembling the preserved fragments, the joints were reinforced with mètallic fastenings. Thus, instead of the leg there appeared an iron crutch. To restore the artistic value of the statue, it was decided by the restoration council to reconstruct the lost fragment of the leg by analogy with the preserved one. The decision was taken considering the museum's traditions (most of the exhibits consist of antique and reconstructed parts). The reconstruction was modelled on a framework made of gypsum putty based on some polymer adhesives with fillings. The recipe of the putty which was worked out in the State Hermitage under the guidance of candidate of chemical science E.P.Mel'nikova made it possible to perform reconstructions with greater stability which is of utmost importance when making a detail serving as a support. The material grinds well, has little porosity, and looks like marble. Besides, the reconstructed part requires less work in making up the details, because it has a similar, though a generalized form a similar but somewhat differing colour.

When preparing the fragments to be reconstructed, we try to stick to a compromise settlement: the reconstructed parts should not be noticeable from the distance the whole exhibited monument is seen, so as not to prevent its perception. In examining the details, the reconstructed parts must be easily seen so that the difference between the original and reconstructed parts could be clearly noticed.

The reconstructed parts can be made of the same material, of some mass imitating this material or of gypsum. In the last decade same new composition made of synthetic polymers imitating marble came into use. In a number of cases they have some advantage over natural stone. We apply some lightstable polymers which do not cause shrinkage or form deformations. In our opinion, the most suitable are compounds of acrylic resins or acrylic and vinyl polymers melts put into moulds made of synthetic rubber. With the help of such technology our restorers reconstructed anew the lost face details on two Roman portraits spoiled by crude restoration in past centuries.

Present-day methods make it possible to remove newly added details without leaving any traces of restoration. That is why, a restorer can afford a reconstruction addition as an interpretation of his time, and it can be removed or substituted by a new fragment without prejudice to the monument.

The survey of special literature shows that little is to be found on the problems connected with the reconstruction of ruined sculpture. Work is being carried on empirically. No generalization of the positive experience and criticism of the negative one have been done, no traditions have been worked out.

On the one hand, the development of modern technology and the application of polymer imitating materials, which can be reversible, gave the restorer a chance to experiment more daring without fear to inflict damage to the monument. On the other hand, lack of information makes every new task on agonizing search causing collisions of opinions. That is why, any information on the work in question will be of great use to the specialists.

SOME THEORETICAL AND PRACTICAL PROBLEMS OF THE CLEANING OF LIMESTONE AND MARBLE

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SUMMARY

It is indispensable for us to know in detail both the chemical and physical properties of deteriorated stone, as well as the quality of the cleaning substances and technologies, their effect on the cleaned stone for the purposes of choosing the right stone cleaning method. The cleaning of stone monuments and other stone objects could bring about harmful by-effects, especially together with the surface treatments without the carrying out of tests and some theoretical considerations beforehand.

Air pollution in recent years has speeded up the decay of different limestones and marbles. The cleaning methods and technologies used for deteriorated stone surfaces depend on the sort, quality, condition, degree of contamination and the structure of the stone. According to Hungarian experiments, the chemical cleaning of limestone, in particular that of our soft limestone, causes harmful salt efflorescence. The high pressure lance, using cold and warm water - if necessary, steam, too - can be used with sufficient result. Irreparable losses may be detected as a result of dry and wet abrasive blasting of Hungarian soft limestone. A mild alkaline gelatinous cleaner does not cause any harm to limestone and marble statues, ornamental part of buildings, etc. In this way the gypsum and other impurities can be removed simply by washing.

In the past few decades a number of publications have dealt with the deterioration of limestone and marble and with the composition of the resulting surface layer of these stones. The majority of the Hungarian monuments were raised from native crude limestone of a very porous structure that has started to deteriorate at high speed as a result of air pollution in Hungary and especially in Budapest. The choosing of the most appropriate method for the cleaning and conservation of stone from among the internationally widespread ones is possible only after the effect of these methods on our native stone objects has been thoroughly examined. This statement holds true in particular for the choice of a proper method of the cleaning of statues and ornamental parts on monuments as well as for individual sculptural objects.
The proper stone cleaning method should fulfil the following requirements:

1/ there should be no chemical reaction with the stone to be cleaned /not even an indirect one/;

2/ the already cleaned stone surface should have the same structure and colour as that of the original stone;

3/ after cleaning no compounds of alien structure from that of the stone, or ones bringing about harmful changes should be left behind on the surface or inside the stone /e.g.: salts having been formed as a result of cleaning and bringing about crumbling after the elapse of a certain amount of time/;

4/ the stone cleaning method should not have a harmful effect on man or nature.

The third requirement is all the more important for the conservation process that might follow the cleaning of limestone and marble, since conserving agents can be used only on the surface of stones which have been completely cleaned, made dustfree and contain no substances with properties different from $CaCO_3$.

In the past few decades several foreign and some Hungarian firms, too, have presented their stone cleaning methods suggested for treating limestones. These processes involve liquid and gelatinous compounds of strong acids and bases as well as the application of sand blasting. Our native soft limestone /especially the one called soft limestone of Sóskut coming from the Buda hills/ is of an extremely porous structure as can be observed in the photo taken by scanning electron microscope.

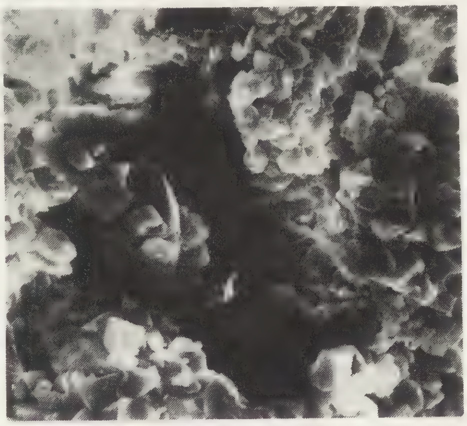

Figure 1/ The porous structure of the crude limestone of Sóskut /x55o/

Figure 2/ Salt efflorescence on the calcite crystals of limestone cleaned by chemical means /x15oo/

After chemical cleaning which is followed by a thorough washing of the surface by water, the cleaning and neutralizing agents that have penetrated the stone throught its pores, will result in salt efflorescence in the course of drying out.

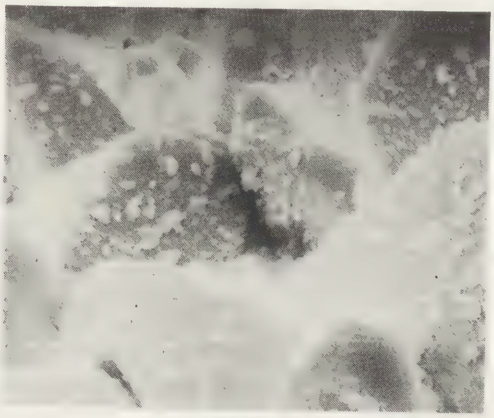

Figure 3/ Salt efflorescence on the calcite crystals of limestone cleaned by chemical means /x15oo/

Therefore these chemical methods do not fulfil any of the four requirements mentioned above for the cleaning of limestone /and, of course, for that of marble, either/. Another large-scale stone cleaning method used abroad for other types of stone /sand-stone, granite/ as well as for limestones of a better quality is dry or wet sand-blasting. Wet sand-blasting - even if only a minimum amount of sand is used - will loosen the structure of crude limestone in a depth of about 1 cm.

Figure 4/ Soft limestone cleaned by high pressure steam and sand-blasting

A further disadvantage of the method is that with its help it is impossible to clean the surface of the deep pores, the sand grains will deposit in the pores of the stone and this fact brings about irreparable losses on the surface of ornamental elements. Besides, it is harmful for the environment /the slow settling of the sand grains, their penetration through windows, the danger of silicosis, etc./.

Mechanical rubbing involves the same disadvantages enumerated for sand-blasting, moreover, it is less effective than the latter /the dirt will remain in the pores/.

For the cleaning of limestone facades and ornamental parts /e.g. cornices/ and especially for carved parts made of hard limestone, cleaning by high pressure water or steam have proved to be much more satisfactory than the methods described above. This was proven by the examination of the form-retaining moulds /Wacker Silikon-kautschuk RTV-M428/ made after the cleaning of the polluted surface of the soft limestone of Sóskut built in a hundred years ago /on the facade of a monument in Budapest/ where both high pressure steam and sand-blasting was applied: the microscopic photos of small magnification revealed that cleaning by steam did not effect the original distribution of pores /the compactness of the stone//Fig.5/, while the specific surface of the stone treated by sand-blasting increased considerably.

In Hungary apart from ornaments to be found inside buildings, the most valuable type of limestone, i.e. different kinds of marble, are used for the making of statues. Under the climatic and air pollution conditions prevailing in Hungary, these marble statues are exposed to rapid deterioration - even if they are covered from autumn to spring /Fig.6/. A hard, black layer will be formed, especially on concave surfaces. For its cleaning the application of a mildly basic paste /the composition of which may be adjusted to the quality and present condition of the stone to be cleaned/ may be recommended that enters into chemical reactions with only compounds other than $CaCO_3$ in the course of a slow ion-exchange reaction, and therefore operates without destroying the original stone material.The impurities to be removed migrate into the stone cleaning agent and the surface - washed repeatedly until a neutral pH level is arrived at - will consist of marble crystals only /Fig.7./.

This method is also suitable for the cleaning of heavily crumbled statues and ornamental parts made of soft limestone.

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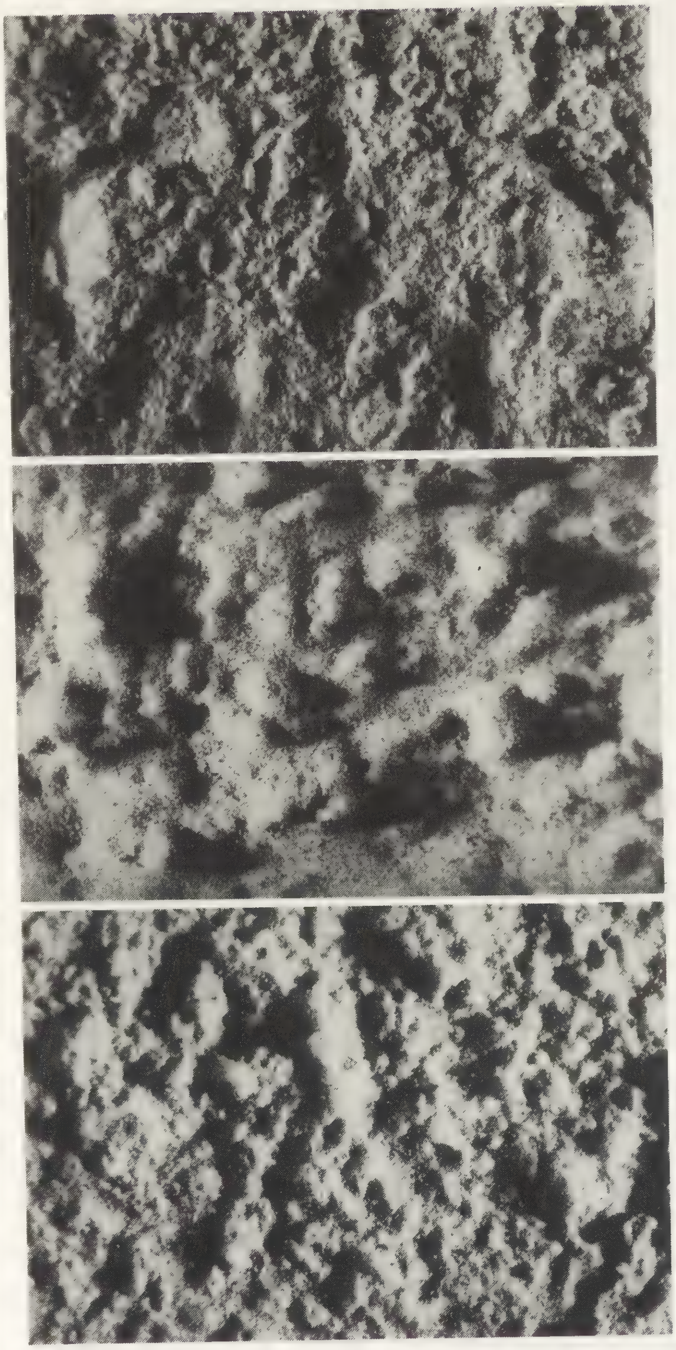

Figure 5/ Form-retaining mould /surface negative/

a/ stone surface before cleaning

b/ sand-blasted soft limestone

c/ cleaned by steam

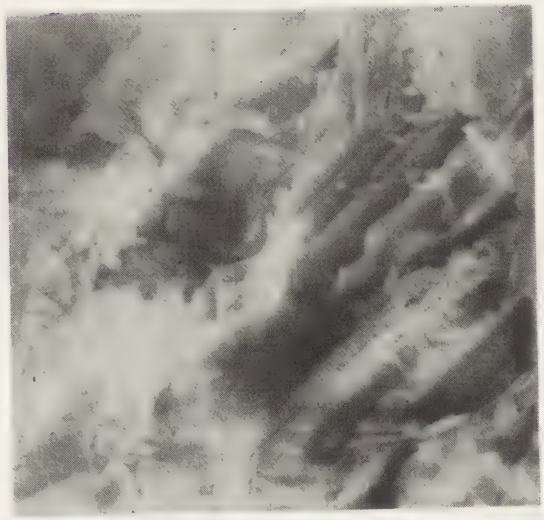

Figure 6/ The transformed, polluted surface of the Ruskica marble /x1ooo/

Figure 7/ The same surface after cleaning by paste /x1ooo/

RESEARCH INTO LIME MORTARS FOR THE CONSERVATION OF RENAISSANCE BAS - RELIEFS FROM THE ELEVATION OF TENEMENT HOUSES AT KAZIMIERZ IN POLAND

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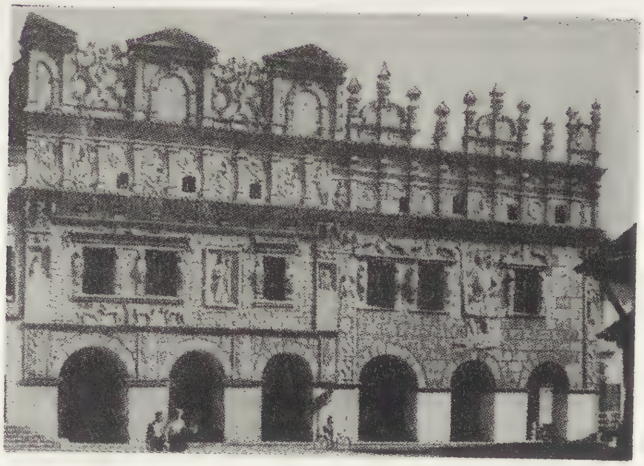

Fig.1. Facades of the "At St. Nicolaus'" and "At St. Christopher's Houses

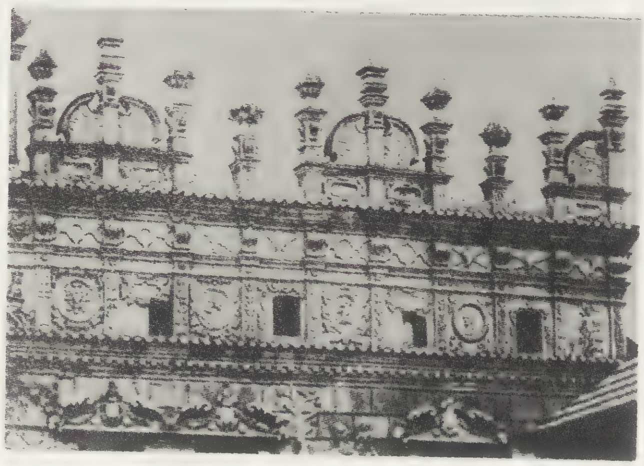

Fig.2. Attic of the "At St. Christopher's" House

SUMMARY

This Report contains findings on lime mortar samples collected for examination from walls and bas-reliefs of a Late-Renaissance Tenement-House, called "At St.Christopher's" in the Market-Place of the town of KAZIMIERZ on the river Vistula in Poland. On the grounds of these findings propositions concerning technology and preparations of the lime mortars of the best appropriateness and similar in their structure, content and constituents to the old ones have been put forward. Proofs on the elevation were executed by Mrs K.Trzeciak, M.Sc., conservator and sculptor, in summer 1983. Their state of preservation is good.

1. INTRODUCTION

KAZIMIERZ DOLNY, Poland, is situated on the river Vistula. As a town it has preserved its old-time urban character /1/. Ruins of the 14th and 17th century Royal Castle, a donjon tower, ruins of another castle at JANOWIEC on the other side of the Vistula River, a Gothic Parish Church, as well as the Late-Renaissance Attic Tenement Houses built around 1615 by Christopher and Nicolaus Przybyła, KAZIMIERZ Noblemen, are reminders of the past. Several other relics include the so-called CELEJOWSKA House of 1635, now restored; The GÓRSKIS' Tenement-House of 1607; A Baroque Church and Monastery, a property of Reformers; St. Anne's Church, formerly a hospital in the 17th and 18th centuries; A Late-18th-Century Synagogue; Wooden Houses from the late second half of the 18th century, and an Early-17th-Century Late-Renaissance Grain Silo situated near the river. The town was revaged more than once, recently in 1915; Now, in its overwhelming part, rebuilt. A tourist-and-recreation centre in view of its historic character and picturesque countryside. The Przybylas' Tenement-Houses in the KAZIMIERZ Market-Place have well stood the challenge of time and still stand these days, little changed and in a rather good state of repair. Both have an almost identical frontal appearance, facades adorned with the images of their saint patrons, Nicolaus and Christopher /Fig. 1/. Ground floors have three arcades each. The storey with one window a little aside, and two twins in the centre. Both houses once had concave roofs /one preserved till these days at "St.Christopher's"/, masked by very high attics /Fig. 2/. An outbuilding with a porch at the first floor forming a kind of passage to the front building is in the rear. Tenement-houses at KAZIMIERZ were built of local limestone, and partly of brick. At present, the "St. Christopher's" House undergoes a process of conservation.

Facades of the Przybylas' Houses are enormously rich in their Renaissance ornamentation, including some original features of the Polish ornamentation school from that time. In addition to the usual architectonic elements, such as e.g. rusticating of the plaster on moulds separating storeys, pilasters dividing and flanking the walls, hermae surrounding the windows and cartouches crowning same, there are also bas-reliefs in plaster - extremely rich in their expression - which go into the make-up of the front ornamentation. Human figures, animals, vegetable and linear ornaments, an entanglement of both Christian and mythological elements, of mediaeval phantasy and Renaissance grotesque, and all this woven together with Latin inscriptions and philosophic and moral sentences in between. The attic has two storeys separated by a massive moulding from each other. The upper one is lighter, having three teeth on it adorned at the centre and on sides with the pinnacles tied by delicate volutes. An identical type of attic is characteristic of the Castle at BARANOW, too; it is rather common for Bohemia. Fragments lacking in bas-reliefs were added or made up more than once over the ages, as confirmed by findings on the samples of plaster collected from damaged elevation areas by Mrs K.Trzeciak, M.Sc., conservator and sculptor. Many of the bas-reliefs have been found damaged to a smaller or greater extent, and both pinnacles and other decorative elements call for urgent intervention of a conservator.

2. LIME MORTARS AS FOUND ON HISTORICAL BUILDINGS IN POLAND

From the 11th century onwards, stone and brick buildings have been erected in Poland by employing technologies inherited after ancient Rome /2/; these technologies were in use for a number of centuries following the fall of Rome in the Bizantine Empire. Monks were the carriers of this science, builders of the oldest sacral constructions. Ancient Romans made excellent lime containing 88-95% of the CaO, calcined from marbles and pure high-density limestones. One of the Roman technologies included a mixture of the fine--ground quicklime and standard sand /requirements resembling ours/. Water added in strictly specified proportions led to the process of slacking; right then, oil was added and so the mixture was ready for use as lime mortar. Insoluble lime soaps produced in the mortar itself made the latter water-tight and resistant to weather hazards. Vulcanic pulver, or "pucolana" used as an additive, entered into chemical reactions with the lime. The "pucolana" was revealed in the ground ceramic brick added to the mortars. In lime mortars from WISLICA you can reveal Estrich gypsum as an admixture to the binder /3/. In the old mortars also limestone happened to occur as an additive, but these were high-purity limestones /as e.g. Tertiary limestone found in the WISLICA mortars /3//. Limestones with clay in them can not be used as they make the mortars swell and crack, unfavourably affecting mortar properties /4/. Presently, organic substances, such as e.g. silicones, come into use as mortar additives producing hydrophobic properties.

3. INVESTIGATIONS INTO STRUCTURE AND COMPOSITION OF THE OLD MORTARS FROM THE PRZYBYLAS' TENEMENT-HOUSE AT KAZIMIERZ

Seventeen samples have been examined, macroscopically through binocular magnifier and chemically in a polarization microscope. The macroscopically observed samples exhibited varying degree of behaviour, cohesion, and resistance to fracture in fingers. Colour of samples ranged from light-grey to cream,with some dirtier spots and patina traces. Samples originating from some authentic sculpture work and from the oldest losses were selected to undergo chemical testing. The percentage of carbonates in the oldest samples ranged from 27 to 39.8 per cent, insoluble matter from 60.2 to 63 per cent. In some samples the percentage of carbonates was higher, up to 44.5 per cent, and that of insoluble matter lower, not exceeding 55.5 per cent. Microscopy of polished section showed high degree of lime mortar carbonatization, the higher the older was the mortar. Sand with rounded grains, up to 0.7 mm in size, was used as a basic type of filler. Among quartz grains there have also been found fragments of magmatic rock, dark in colour, quartzites and feldspars. The sand itself comes from the river Vistula, as proved by comparative studies. In samples containing large portions of carbonates, fragments of limestones up to 5 mm in size could have been spotted amidst filling material. In some of the samples one can notice small chips of red ceramics. The binder proves to be microcrystalline in its character, well tied up with the filler grains. Among sculptors' relief fragments, made up after the second world war, the presence of cement-and-lime mortars grey in colour and varying clearly from the authentic material and older, lime-mortar,fillings could be traced. Work carried out leads us to the conclusion that lime mortars used contained binder and filler in a proportion as 1:3.

4. PREPARATION AND VERIFICATION OF MORTARS MADE TO RECIPES PROPOSED.

4.1. Materials used for mortars.
The following materials and additives were employed to prepare tentative mortars:
- Six-month and thirty-five-year lime putty, ground quicklime /not slacked/;
- Mixed sand with grain-size distribution of 3.53 according to PN-79/B-06711 Specification coming within the field of a good graining, standard sand with grain size not exceeding 2 mm, and the river sand from Vistula;
- Ceramic brick chips 1 to 2 mm in size, fine limestone fragments from KAZIMIERZ deposits with an admixture of silty matter ranging from 0.5 to 3.0 mm in its grain size distribution;
- Hydrophobic agents, such as low-molecular methyl-silicone resins in a mixture of toluene and ethylene dichloride, used as a 5% solution in the extraction naphtha, silico-organic compound used in 1:1 dilution with organic solvents and oil.

4.2. Findings on Mortars Proposed.
Tentative tests were carried out with the use of lime putty and sands to find out correct proportions of binder and filler and the required amount of water to achieve the assumed plastic constistency of mortars. In the 1:2 and 1:2.5 mortars cracks made themselves conspicuous on samples: the 1:3.5 and 1:4 mortars were weak, and crumbled under the pressure of fingers. With the proportion of binder to sand as 1 to 3 strong constant--volume mortars were produced. In the successive samples a certain amount of sand was replaced by an addition of the ceramic and limestone chips in a proportion of 10% to 25%. Limestone chips gave negative results, for the mortar was weaker. An addition of the ceramic chips, on the other hand, increased compressive /crushing/ strength, water resistance and substrate-adhesion qualities. Ceramic chips lend mortars a warm creamy colour. Tests were made with methyl-silicone resin or silico-organic compound added to the make-up water in the proportions of 1% or 0.5% respectively. Said additives have been found to improve resistance of mortars to the action of water. No special differences have been disclosed in the properties of solidified research mortars after one year of hardening, with the six--month and thirty-five-year lime putty used as stock material. Preliminary tests with the use of burnt lime, non-slacked, in a proportion as 1:3 and 1:4 as well as sand, ceramic chips and oil added in an amount of 1% compared to the percentage of binder gave in effect constant volume 1:4 mortars. All in all, 45 tentative mortars were made. As a result of this, six mortars that gave best results as regards constant volume and mechanical characteristics were chosen for further tests. For composition of these mortars and practical experience on their use refer to Table 1.

4.3. Hydrophobisation Tests.
Tests in which surfaces of the mortars were protected by hydrophobic media /It.4.1/ were completed on samples left to cure for three months under dry-air conditions. Samples coated with methyl-silicone resin /film of resin applied two times by brushing/ showed that absorption time of a drop of water was

TABLE 1 : FINDINGS CONCERNING PROPERTIES OF LIME MORTARS CHOSEN AS A MATERIAL FOR THE RECONSTRUCTION OF SCULPTORS' RELIEFS IN THE PRZYBYLAS' TENEMENTS

Mortar Ingredients		Absorbability	Compressive Strength		Mortar-Brick Adhesion	Time Water Drop Needs to Permeate into Mortar		
			When dry	When saturated with water		Surfaces unprotected	Surface protected by methyl-silicone resin	Surface protected by silico-organic compound
		%	MPa	MPa		sec.	min.	min.
Lime Putty: Mixed Sand as 1 : 3	No additives	10.5	0.94	0.72	good	4	85-100	78-105
	Ceramic debris added to sand, 10%	11.0	1.69	0.82	very good	14	105-145	95-125
	Methyl silicone resin added to the binder, 1%	10.7	1.19	0.65	good	14-40	-	-
	Silico-organic compound added to the binder, 0.5%	10.1	1.66	0.94	good	30-60	-	-
Quicklime: Sand as 1 : 4	Ceramic debris in the standard sand, 25%; plus Oil,1%	8.8	0.35	0.30	good	min. 60-80	-	-
	Ceramic debris in the river sand, 20%; plus Oil, 1%	8.5	0.40	0.36	good	75-100	-	-

six to twenty times longer than that on unprotected mortars. Drops had the shape of an ellipsoid of revolution, and such a shape persisted for almost sixty minutes whereafter it changed into a flat-convex lens and it was only then that water slowly began infiltrating into its substrate /100 to 145 minutes the longest/. With the mortar surfaces protected by silico-organic compound, the time of permeation got a little shorter /from 105 to 125 minutes/, but drops remained almost unchanged in their shape and behaviour. Samples of mortars having no surface protection had invariably shorter times of permeation, from 4 to 14 seconds. Water drops initially took the form of flattened lenses whereafter they gradually spread and percolated. Mortars that were prepared with preventives added right to the make-up water showed a little longer time of percolation, ranging from 15 to 60 seconds. Surface protection measures as well as internal hydrophobic additions have shown therefore to produce good results, compared with the unprotected mortars, with the only reservation that surface protection measures must be repeated every now and then at some half-decade intervals.

CONCLUSIONS

The oldest mortars as used for the making of bas-reliefs on the Przybylas' Houses have the lime-binder - filler proportions established on a level as 1:3. The river sand /from Vistula/ with some ceramic brick debris and in some cases also limestone debris added thereto found application as fillers. The mortar itself is highly carbonatized, fine-crystalline in its structure, and forms reliable mortar-filler bonds. Properties of lime mortars from the more recent supplements seem worse. As a result of work conducted on mortars prepared acc. to various recipes the best mortars have been chosen, as shown in Table 1.

Outstanding in their properties are mortars with 10% addition of the fine ceramic brick debris as well as mortars with an addition of the silico-organic compound. Mortars made of burnt lime and ceramic debris as well as oil admixed thereto have lower compressive strength, but are better as regards absorbability and hydrophobic properties. Trials made in 1983 with lime mortar having also a percentage of ceramic debris, applied right to the elevation, have now been found to have stood well the hazards of time and weather.

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THE RESTORATION OF ARCHAEOLOGICAL MONUMENTS IN THE TROPICAL CLIMATE

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Summary

On two examples, the restoration of a big Bodhisattva sculpture in Sri Lanka and the work on an ancient Maya site in Honduras it is demonstrated that in the tropical climate various destructive agents are effective in attacking the stone. A thorough analysis of the causes of decay is necessary to find out the most effective methods for conservation. Of peculiar importance in the tropical climate is the application of preventive methods, acting against the destructive forces, for the usual methods of surface protection and impregnation for consolidation prove to be not of a long lasting efficiency in these regions. Most of the damage on stone in tropical countries is due to the action of humidity, bringing salts from the ground into the stone, dissolving its surface, weakening its strength by an accelerated weathering of the minerals and causing the growth of microorganisms and vegetation on the surface. If a permanent survey of the object by cleaning and reapplying hydrophobing coatings is not possible, effective technical means are necessary to prevent humidity from entering into the stone.

The experience of the Rathgen-Research Laboratory in Berlin on the field of the preservation of monuments is based on an intense research on the causes of decay of natural stone and the possibilities of maintenance of historical structures. In 1970 the state of the technical possibilities for stone conservation in Germany were summarized (Lit. 1-5). For southern Germany all restorations on monuments and sculptures were documented and evaluated with respect to their effectivity (Lit. 6, 7).

The results of the practical work in Germany could be applied in Greece and Egypt (Lit. 8-12). In Greece the phenomenons of stone decay had to be analyzed on the island of Samos, where the German Archaeological Institute excavated a big temple of Hera. On this place a rapid decay of stone had to be observed, worser than that of the Acropolis at Athens, though at Samos certainly air pollution was not the cause of stone decay. At that time the causes of decay of the marbles of the Acropolis were discussed with the anticipated result that air pollution was the main damageing agent, though no measurements of the amounts of pollution substances in the air were ever determined, a study of earlier states of preservation of the buildings on the Acropolis, which is well documented by a great number of early drawings, was never undertaken and the condition of marble monuments from the 19th century in Athens, which withstood air pollution over two centuries without any loss of substance, was completely ignored. Last not least from the Caryathides of the Erechtheion sulfates were determined though the stone had been impregnated many times by sulfate solutions when plaster casts were made and one did not hesitate to copy also in 1976 the Caryathides by plaster moulds, though silicon moulds could have been applied at that time.

Those scientific absurdities, which occured in the period of the recent investigation of the Acropolis were the reason why for two projects in tropical countries, where again an extremely rapid decay of stone had to be stated, though air pollution was completely absent, much research work was invested into the determination of the causes of damage, with the result, that a great variety of different forces attacks the stone. These must be all considered in order to assure an effective and longlasting preservation of the objects.

One archaeological site threatened by a rapid decay of stone is a sanctuary of the Mayas at Copan in Honduras. Copan is situated on the 15th degree of latidude north of the equator and by that in a region with a typical tropical climate, which is determined by a rainy season from june to december, with heavy rain showers and thunderstorms in the evening. The temperature varies between 20-24 centigrade, the average rainfall during the raining season is about 200-250 mm.

In this region the Mayas built a sanctuary in the time from 400 to 800 AD. In 800 AD this place was abandoned. In the 16th century the ruins of Copan were found by spanish conquerors. In the 19th century excavations started and lasted until our time, when the Instituto Hondureno de Antropolia e Historia took charge of the excavations in 1947.

The archaeological remains are scattered over a region of 3 x 3 km with a sanctuary of 400 x 400 m in the central part. Arranged along the sides of two big yards of the sanctuary there are several temples and related constructions. The surrounding buildings are not yet excavated and covered by a thick layer of soil and vegetation. A study of recently excavated buildings reveals the rapid attack of weathering on the surface of the stone. Mortar is rapidly washed out of the joints and ground moisture causes a decay of the lower positions of walls.

To counteract this decay of the archaeological remains of Copán first the stone of the buildings and sculptures was analyzed petrographically. Copán is situated in a region with creaceous sediments and younger vulcanic rocks like andesites, rhyolites and ignembrites. A study of thin sections revealed that different types of these vulcanic rocks were used causing different phenomena of weathering. For the sculptures a greenish andesite with larger feldspars was used. Characteristic for this type of rock are inclusions of bowls of a hard basaltic rock of a greyish colour. This type of andesite contains also small inclusions of a soft and porous material, which is rapidly washed out by the rain, causing by that a surface full of holes.

The stone of the pyramids and walls are also andesitic, but of a considerably harder type of rock than that used for the sculptures, but it too reveals a permanent loss of its surface. The most common types of stone decay are a powdery decomposition of the stone's fabricon its surface, the formation of small globular holes, the formation of fissures of different dimensions and the peeling of shells of a thickness of a few centimeters.

The powdery decomposition occurs on all types of stone. Physical and chemical forces cause a breaking up of the binding of the minerals and a loosening of the clayely components, which are rapidly removed by heavy rain showers. The eroding action of the rain becomes obvious by the fact that the intensity of weathering is different on the four sides of the stelae. On one side, for instance the original paint is still visible, while on the opposite side hieroglyphs have become almost underdecipherable.

The second type of decay, the separation of larger shells from the surface is a peculiar threat, for the loss of substance is considerable when they break off. Such destructions occur in the zone of ground moisture and on those parts of buildings, where water cannot run away, like on staircases with a wrong fall of the steps. On one famous monument, the hieroglyphic staircase, where all vertical parts of the steps are covered with inscriptions, a considerable loss of these decorations is due to these types of decay.

The globular holes on flat surfaces are due to the washing out of clayey inclusions. These holes are almost permanently filled with water, causing a rapid progress of decay in these parts of buildings, walls and offering tables.

Microfissures crossing the stone as a narrow network occur frequently on stelae. They may be due to the mechanical shock when they had collapsed. These fissures offer further possibilities for the humidity to penetrate the stone, causing a chemical decomposition of minerals in this zone. Macrofissures were already present before the stone was worked. Later they broke up, causing in some cases the splitting of larger blocks of stone.

From the study of the phenomena of decay it became obvious that the action of humidity is the main cause of the

weathering of stone at Copán. It enters from two sides into the stone, first as rain, second as ground moisture rising by capillary action. Stones buried in the soil are permanently soaked by the humidity of the wet soil. The action of humidity on stone is a chemical one: a transformation of silicates into clay and a decomposition of iron minerals under formation of iron hydrates. Besides that salts are transported in the stone and an intensive microflora finds an ideal environment for growing. The chemical action of humidity on stone is almost equally distributed over the whole object, the action of salt crystallization is restricted to the lower positions of structures.

Physical action seems to be less important on stone surfaces compared with chemical attack. The variation of temperature on the surfaces of stone does not exceed 50 centigrades, even when cool showers hit a stone heated up by the sun during the day.

After the study of the causes of decay and the action of the destructive forces methods for preservations could be proposed. For the consolidation of stone silicate ester was proposed. Their low viscosity guarantees a deep impregnation, preventing by that the formation of superficially hardened crusts. Silicate esters have the further advantage that they can be mixed with hydrophobing materials, preventing a further entering of humidity in the interior of the stone. Silicate ester consolidate the surface and connect those thinner shells, which have not completely separated from the stone. For the connection of thicker crusts or already completely separated pieces epoxy-resins are recommended.

Besides the treatment of the stone against a chemical attack a treatment against the growth of microorganisms is necessary. For this products like Thaltox, as well as Chlorox and Borax are already in use in Copán.

Finally, a certain number of constructive work has to be done, first of all installations are necessary to prevent rain water from remaining on the horizontal parts of the stonework.

Similar problems like in Copán were encountered at Maligawila in Sri Lanka. In 1971 at this place a sculpture of a Bodhisattva was found in the jungle. The sculpture which is 9 m high has collapsed and was blasted into more than 100 pieces with dynamite by treasure hunters.

The remains of the sculpture are found in a big sacred area with a great number of remains of temples and other structures which are gradually excavated by the Archaeological Department of Sri Lanka. The main material used for sculptures in this part of Sri Lanka is an extremely coarse grained marble with calcite crystals of several centimeters length. The marble is very fragile and already a weak mechanical stress causes a breaking into pieces. The surface of marble objects usually is smooth and covered by a black crust of microorganisms.

To study the causes and the mechanism of stone weathering in this region again samples were analyzed first of all by means of thin selections in the laboratory. The main destructive force is here like in Honduras the chemical action of rain, entering into the stone on the cleavages of the calcite, causing a separation of the calcite grains and by that a weakening of the whole fabric. The solution of the calcite grains on the surface leads to a slight roughening which provides a basis for the growth of microorganisms. These microorganisms are reponsable for a further decay of the stone on its surface which gradually is removed leading to rounded forms on sculptured objects.

The main restoration work on this place was a joining of the broken pieces. For the larger pieces dowels of stainless steel up to 5 cm diameter were used. Epoxi resins were used for glueing the fragments. For the consolidation of the fragile surface a solution of an acrylic resin was used. To prevent the action of rain-water and the growth of microorganisms the whole sculpture will be treated with a silicone solution. This treatment shall be repeated every five years for the heavy rains cause a rapid decomposition of hydrophobing coatings.

The two sites in tropical regions, where antique monuments were restored, show that also in a non industrial climate the decay of stone proceeds rapidly and causes a considerable loss of objects of historical importance. To preserve them for the future the mechanism of stone decay has to be studied in order to propose effective techniques of restoration. Besides the repair of existing damage precautions are necessary to prevent the continuation of decay and for that technical installations sometimes are necessary.

THE DETERIORATION AND CONSERVATION OF POROUS BUILDING MATERIALS IN MONUMENTS. A LITERATURE REVIEW. SUPPLEMENT 1984.

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Summary

In this third Supplement after the publication of the original review by ICCROM in 1976 the most important literature published in the period 1981-84 is briefly reviewed.

1. Introduction

This is the third Supplement to the original review which was published by ICCROM in 1976 (12)* and contained papers presented by the authors to meetings of the ICOM Committee for Conservation in 1967, 1969 and 1975. The two previous Supplements were included in the Preprints of the Zagreb 1978 and Ottawa 1981 meetings (13, 14). The present Supplement is even more selective than the previous ones. It is brief and contains relatively few references to recent literature. The main reason for this is the publication of what is probably the first real textbook devoted exclusively to the subject matter: Stone Decay and Conservation by G.G. Amoroso and V. Fassina (1). Each of the 18 chapters of this book contains copious up-to-date references. Numerous graphs, tables and black and white photographs accompany the text. In accordance with a previously noted trend most of the relevent papers have been published in the Proceedings of but a few Symposia. One of these Mortars, Cements and Grouts used in the Conservation of Historic Buildings, Rome 1981 and another Materials Science and Restoration held in Esslingen (F.R.G.) in 1983 which contains only a limited number of papers directly pertinent to monuments (6, 17). The Conservation of Historic Buildings by Bernard M. Feilden - the former Director of ICCROM - was published in 1982. It contains an extensive bibliography, a useful glossary and is very well illustrated. This book is primarily written for architects, engineers and surveyors (2).

2.3.4. Mortar and plaster.

The diagnosis of weathering phenomena and the choice of conservation methods require an understanding of the composition and structure of the materials. A number of papers has been published on the analysis of ancient mortars and plasters and the problems involved in interpreting the results (7). Mortars examined included samples from Afghanistan and Venice. Plasters came from monuments in Rome and Venice.

3.4. Thermal aspects of moisture in porous building materials.

Schickert and Böttcher (11) have applied infrared thermography to the study of moisture distributions in walls. They used infrared heat radiators to detect reflected radiation as well. They claim that dark areas in the resulting thermograms (which they very confusingly call reflectograms) are mainly due to absorption of 3 micron radiation by water in the moist parts of the wall. The interpretation of such mixed registration of emitted and reflected radiation seems complex and this approach has not yet been applied to monuments.

4.4. Dust pollution

The role of sulphur dioxide as the originator of crusts on stone and in particular on lime stone, was challenged in 1973 by Riederer and critically discussed in our Supplement 1975. Work by Šrámek (1980) leading to the opposite conclusion was discussed in the Supplement 1981. This issue now once more demands a close reassessment. In two papers Grimm (3, 4) has explained why he is inclined to corroborate the view of Riederer that sulphur dioxide could not be held directly responsible for the development of gypsum crusts on limestone and marble.

After compiling an inventory of all stone varieties used to erect buildings in Munich, and, after doing the same with the quarries (granite, limestone, marble) from which the building stone material was obtained, Grimm made also an inventory of all reparations and renovations that had been carried out since 1940 on various buildings in Munich with stones from the same quarries. Optical examination of the surface of the stones used for restoration, revealed that the gypsum crust on them was not the product of transformation of the limestone itself, caused by the sulphuric acid aerosol in the air of Munich. Gypsum, already formed elsewhere, was undoubtedly brought on the stone surface and once there it was glued to the stone by organic dirt present in the air. Besides, when the interface stone/crust was examined, it showed a regular, continuous separation line undisturbed by any interference of the crust with the stone, a sign which was taken as evidence, that the crust had not originated from the stone. More likely it was brought from without, either as gypsum or limestone dust. Sulphuric acid aerosols converted it subsequently into gypsum.

Another interesting aspect of Grimm's study was the discovery that the roughness of the stone surfaces, while being measured with a special device, increased continually (shown as a straight line in his graphs) and not progressively (shown as a hyperbolic line), whereas, considering the progressive increase in concentration of sulphur dioxide in the air, the progressively rather than the continually aggravating roughness profile was to be expected. This, and, besides the observation that, about the year 1960 the lines in his graphs representing the roughness of the stone surfaces flattened markedly, led eventually to the deduction that the ever increasing concentration of sulphur dioxide in the air from 1940 till 1980, actually slowed down the rate of corrosion of the investigated stone.

The above cited previously contested thesis of Riederer is now, although indirectly, also sustained by Rödder (9). He observed that the series of samples taken from natural stone and pre-treated with a solution of sodium sulphate when made water-repellent by means of siloxanes and then submitted to accelerated aging in an environment polluted with the average sulphur dioxide concentration, showed at the end of the test an advanced deterioration. The reference sample (that is the sample that was not rendered water-repellent) was, in the course of the test even reduced to a powder. On the contrary, the samples of the same natural stone, which were not pre-treated with sodium sulphate, but otherwise were given the same hydrophobicity, and underwent the same aging, showed no noticable deterioration. The most spectacular point in this experiment was however that the reference sample emerged from the testing unchanged which was in contrast to the common belief that unprotected lime stone is vulnerable to sulphuric acid. This, according to Rödder, justifies the conclusion that humid air polluted with sulphur dioxide, does not necessarily attack natural stones.

5.1.1.5. Remedial measures against moisture. Electro-osmosis

Wittmann (18) measured the electro-osmotic permeability coefficient of some stones and mortars. He established that the values of this parameter are negative in lime mortars. This would imply that when an electric field is applied the flow in the mortar would be upwards instead

* The decimal headings in this paper correspond to the chapters in the 1976 review.

of downwards as in the stone. Therefore in walls of most monuments the flows of moisture in stone and mortar would largely compensate each other. The high voltages required (200 V) to obtain only low electro-osmotic pressures (8 mbar) in sandstone, for example, lead to the conclusion that electro-osmotic drying is not feasible for walls in monuments.

5.3.4. Silicone esters

With respect to the reactions during the curing of silicone esters, Snethlage (15) reported that from his measurements of water-vapour sorption carried out on sandstone, he was able to conclude that the alkoxy-silane (i.e. a silicone ester), after having penetrated into the stone, reacts with the water layers absorbed on the walls of the pores (this is called 'rigid water', cf. Supplement 1981, section 2.1) undergoes hydrolysis and finally solidifies as silicagel. Therefore in order to consolidate porous stone the silicone esters consume even that moisture in the stone which under normal conditions is otherwise irremovable. Consolidation of stone by silicone esters has then the secondary advantage of drying the stone as well.
The usefulness of the silicone esters as stone consolidants is enlarged substantially if they are applied, not as monomers (the chemical term for these is alkoxy silanes) but as moderately polymerized materials which are called oligomer alkoxysiloxanes. The latter is in the view of Roth (10), due to the fact that they are practically non-volatile and retain their quantity during the curing process. Because of this they are very likely to consolidate porous stone satisfactorily.

The performance of organo-silicon compounds has been studied by Mavrov (8). Data obtained by testing these materials as to their ability to form sound protective barriers led to some rather disappointing conclusions which are summarized here.
- Products containing monomers - and these comprise most brands of common sandstone consolidants - are worthless in this respect as through the curing process they solidify as amorphous silicagel, which acts as a sieve rather than a barrier.
- Oligomers included in water-repellent formulations as well as in stone consolidants do solidify as films. The films carry however many holes and cracks. These defects are in the view of Mavrov certainly the consequence of internal strains which develop in the film during and after curing.
- Impregnation with oligomers or polymers like silicon resins leads initially to the encapsulation of salt deposits in the stone, rendering them thus harmless as far as corrosion of the stone is concerned. However, due to the above mentioned physical internal strains, the encapsulation is soon jeopardized by cracks, through which moisture is again absorbed by those salts. Impregnation with these compounds is therefore not remarkably effective in preventing the process of deterioration.

5.3.5. Silicones

De Witte et al (16) have tested many brands of water repellents. Most of them contain organo-silicon compounds dissolved either in water (siliconates) or in organic solvents (siloxanes). The test results indicated that solutions of 10 % imparted to the stone a water repellency that lasted the longest. Solutions of 5 % delivered water repellency which broke down half way through the test. It appeared, moreover, that solutions of 2.5 % - the most commonly used concentration in practice - were responsible for the poorest water repellency.
Heising (5) has reported that the rising moisture content in masonry can be reduced and arrested in the following manner: Holes are drilled in the masonry (distance between the holes is 150 mm, their diameter is 30 mm, their length amounts to the thickness of the masonry wall minus 5 cm and the angle of drilling is 45-30°). Impregnation by way of the holes allows the water-repellent to diffuse around each hole so that through overlapping of these spheres of diffusion a horizontal barrier (a damp course) is formed. The liquid injected in the holes consists of either hydrophobic silicates or siliconates or methylalkoxysilane (all of them being used as solutions in water). By impregnation with these chemicals which normally lasts 24 hours, no pressure is applied, and pre-treatment of the holes with water is a requirement.
An alternative to the previous treatment is injection under pressure. In this case the water repellent is a siloxane dissolved in an organic solvent, the distance between the holes varies from 100 to 150 mm and their diameter is about 12-18 mm. The pressure applied is 3-7 bar.

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Section 11

History and Theory of Restoration

Théorie et histoire de la restauration

THE COMPLEMENTARY ASPECT OF RESTORATION

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Summary
Restoring modern art objects it becomes ob= vious that fundamentally new considerations in connection with restoration-theory are ne= cessary. These considerations are also ap= propriate to restoration of ancient art newly to determine the position of the restorer.

In the new situation of modern art, the need for restorers rehearsed in traditional methods of restoration to adapt to new conditions has only gradually become apparent. From about the beginning of the "sixties", there are clear signs that the old routine is inadequate and that new strategies are wanting. Most of all, there is the impression - soon to become cer= tainty - that extant restorational attitudes are not enough.

Art has acquired an element of the general. More than the Middle Ages, for example, art can now only be understood as a part and an expression of its own time, our way of think= ing. Its public nature and variety mirror our life, both the technological revolution and our fears and longings.

The material and not the subject is the obses= sion of modern art. Art historians have long striven, like Georg Kübler, to combine the history of art with that of materials. For all the qualifications this art has brought upon itself, the restorer is still faced with the need to act with usual care. In that sense the art of restoration would not seem to break with tradition even today.

At this point closer examination reveals what first seems a contradictory phenomenon, inex= plicable in itself and confusing for the restorer looking for what to restore. For one, there is art that is expressed in acrylic per= fection, hard and immutable; then there are objects conceived all along with decay in mind. This Janus-head of modern art does seem to present a paradox, and it could cloud the task of restoration in hand: would one not influ= ence or even dominate the other? These fears are not substantiated. At first, there is no evident connection between the two areas of modern art, that of unchanging perfection on one part and of soft, disintegrating epitomes of vulnerability on the other; between the de= finite link with tradition in painting in the classical sense and in its composition, and the new material decay founded on ideological ground. These phenomena seem to be mutually exclusive; but they are also together represent the com= plete image of modern art. Nils Bohr calls this relationship of exclusion and completion com= plementary.

Modern art has aroused questions which might be waiting for the "complementary relation= ship theory" to supply satisfactory answers. This method of consideration is not for ana= lysing a particular object, but to establish basic principles. The seeming contradiction in modern art referred to earlier should be understood as complementary in the sense that, taken together, the two elements will supply all the information about the object.

The eminent philosophical significance of this concept may be a first step toward a new un= derstanding of modern art and its apperently divergent ideals. The concept of complemen= tariness gives us a basis for dealing with what first appear as self-contradicting si= tuations in a non contradicting way. Paradoxi= cal starting-points encourage the working out of logical solutions for such unexpected con= tradiction the impressions so gained from an object converge to form an intelligible image - and thus define what the restorer has to do.

CRITICAL EVALUATION OF DATA ON THE COMPOSITION OF ANCIENT MATERIALS. PART I: STRUCTURAL COMPONENTS OF THE PAINT LAYER. PART II: PAINTS AND TECHNIQUES

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SUMMARY

The major failing with comments on the examination of paintings has been an unfamiliarity with basic techniques of oil painting. Mistranslation of early manuscripts can confuse the issue, while recent scientific examination must be interpreted with caution. This article deals with our investigation into various recipes and formulation of materials for oil painting, including a review of techniques and going into detail over the traditional treatment of ingredients. The listing covers methods of painting from medieval times to the twentieth century.

Topics discussed include the relationship between materials and techniques and the survival of the painting. Understanding of a multitude of materials and relationships, of the concepts that determined their historical use, and of the influences and relations between schools, thus becomes a requirement both for the conservator and the modern artist.

I. Structural components of the paint layer

> "A painting... is a plane covered with patches of color on the surface... filling up the outlines... When the artist wishes to begin, after he has laid the gesso on panels or stretched canvases and smoothed it, he applies over it with a sponge four or five coats of the softest size, and grinds the colors with walnut or linseed oil, though walnut oil is better as it yellows less with time. When they are ground with these oils, which is their vehicle, nothing else is needed... But first there must be made a mixture of siccative colors such as lead white, driers, and terra da campane... and when the size is dry this must be applied... so that it becomes even... and this is called imprimatura [i.e. oil priming.]" (Vasari, 1550)

Speaking about panel painting, Van Mander says in his account of Jeronimus Bosch: "... he drew on the white [gessoed] panel; he then applied a transparent flesh-colored priming, allowing the ground to contribute to the final effect of his work." Elsewhere Van Mander remarks: "They drew on the white ground and laid an oil priming over the drawing." (1)

The usual oil ground (2) is composed of one up to four coats of oil priming applied over a sized canvas; each size coat is pumiced when dry; each priming coat, applied with the trowel or large brush, is pumiced when dry, except the last one (3). According to De Mayerne, vulgar ceruse contained up to 50% chalk. The color of the ground is given by the red or yellow ochre, by charcoal black, and by umber which, in the case of an oil ground, is used in the proportion of 2 ozs. umber to ½ up to 2 lbs. bolus or 1 oz. umber to 1 lb. lead white. No essential oil is mentioned. Umber serves as drier. The picture is further constructed according to the conception of the artist (4), the laws of the surface (5) and of perception (6), which influence not only the artist's world outlook (7), but also his technique (8). We will further discuss the materials used in oil painting. For pastel (9) and water-media (10) see our previous papers.

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A few observations are in order on the large number of samples of either oils (cold-pressed linseed, walnut, poppyseed, sunflower, safflower, and soy oils, purified, clarified, cooked, and thickened oils, etc.) or varnishes we have collected and examined (11):

- No visible darkening occurs in cold-pressed or refined oils when stored in the dark for over three years. However, a deposit is present in those oils originally less bleached.

- Walnut oil cold-pressed needs to be clarified and purified as the amount of deposit is greater than in any other oil, about 10-20% by volume.

-It may be assumed that darkening occurs upon drying. Nevertheless, except under severe test conditions for a specific pigment, such darkening in a properly formulated paint using a properly bleached and clarified linseed, walnut, or poppy oil, is not noticeable in the actual painting.

-As to both sunthickened and Stand Linseed Oil, pigments are hand-ground with much difficulty in such a vehicle and the paste is workable only with the help of much volatile diluent. As there is no evidence for the extensive use of volatile spirits up to the eighteenth century except for specific and limited purposes, it may be assumed that the two mentioned vehicles were not largely used in painting. See Volpato (12) for instance: ground colors are kept in folded papers, saucers, bladders; lead white is kept in a vase with water; palettes with colors are placed in water after lake, verdigris, and similar colors, are taken off the palette; brushes are cleaned with linseed oil and kept in it, only the large ones being cleaned with water and soap; no mention is made of turpentine or petroleum distillate except for diluting blue colors.

- The results of our inquiry may be summarized in a few words: all the not very scientific expressions used by De Mayerne, such as "white and clear like rock water" i.e. bleached, "flowing like a varnish," "white and very pure liquid linseed oil" (subtile i.e. refined,) etc., - accurately describe the final product obtained in each specific case (13).

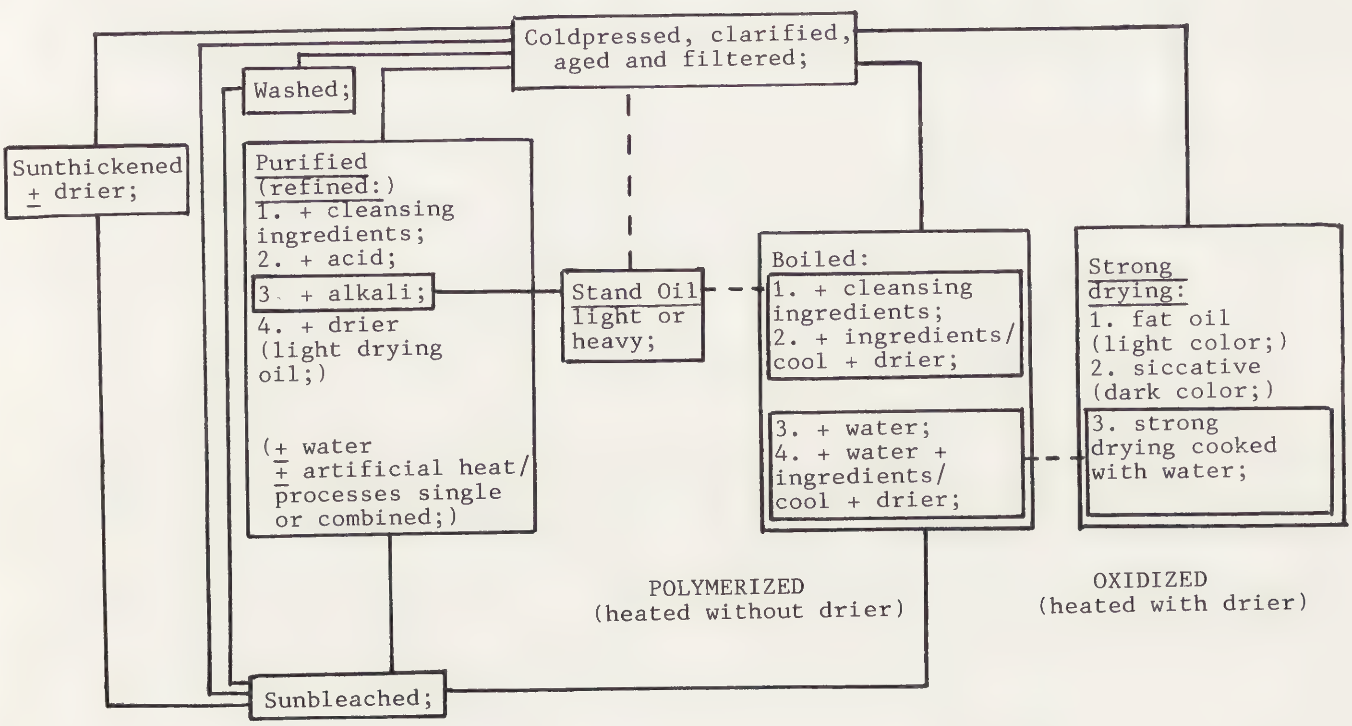
We were told by a Dutch Colorman that a rather dark and thick oil cooked in open kettles, rather similar to Stand Linseed Oil, has been in use in the Netherlands for house paints. De Mayerne speaks only about cooked oil of the same type used for printing inks. As it also asks for specific modern technical conditions, there is thus no evidence for the use in painting of Stand Oil (polymerized oil) in its actual form, prior to our century. Furthermore, the property of polymerized oil to draw up like a thread is described by De Mayerne as being the property of thick and sticky varnishes (fil de vernix) obtained after adding a resinous ingredient to the cooked oil and further cooking. The usual cooked oil has

at most the plastic flow of a rather concentrate spirit varnish (14). Water in such empirical methods has the scope of obviating burning and darkening of the oil when temperature rises. There is no precise delimitation between the groups of formulae using water and heat, except under test conditions where temperature may be kept above or under 250°C. In fact, they may be roughly divided into light drying oils (around 100°C) and either partially oxidized or partially polymerized oils in relation to the presence or not of metallic driers. Although the role of heat was known, it may be assumed that heat-processing was done mainly in view of purifying the oil, polymerisation being an ignored result of the process. Proof of this assumption are the ingredients used besides heat. Thus this rather delicate and risky procedure has been abandoned in favor of the usual refining methods. A very interesting recipe of German origin, quoted by Merrifield, recommends the use of sorrel (*rumex acetosa*, rich in calcium oxalate) for the purification of oil (15). About a month of exposure to sun and air is sufficient to obtain an almost colorless, well clarified, and fluid oil.

Most varnishes were prepared by heat. As De Mayerne recommends that a picture be varnished in order to protect it, and the letters of Rubens suggest that Susterman could retouch the master's painting sent to Florence, it is an obvious conclusion that many pictures were varnished only long after their completion. In fact, practice shows that an *alla prima* picture executed on oil ground with colors ground in raw linseed, walnut, or poppy oil, and thinned with the same raw oil, eventually with some cooked oil added as drier, is glossy enough after completion and does not need any varnishing. It is so glossy, that it asks for the scraping Pacheco recommends before glazing or repainting (16). Oil paintings were executed on a provisory stretcher, then rolled up, the painted surface facing always outwards, for keeping or mailing. The same procedure was followed by Van Gogh and Bonnard (17).

As we were not concerned with identifying the presence of a certain oil or resin in a painting, but with the classification of processes according to raw materials, procedure, and results expected, in view of obtaining a medium fit for use, we reproduced all the formulae quoted in De Mayerne's text in exactly the same conditions as described. Regarding resins, identification of their components is of no importance to the painter; the main problem has been to locate finest quality supplies: we could obtain three different qualities of Venice Turpentine, which usually must be filtered; finest Chios mastic, and damar of unspecified origin; sandarac and benzoin. As for copal (18), mentioned only once and with some doubt by De Mayerne, we could locate only a semihard Congo copal; it can be treated by the usual gum running process. No fine quality amber was yet available to us (19). All the varnishes obtained result identical to the description of De Mayerne and usually lighter than a similar trade product (20). We suggest that only an attentive reading of the actual formulations and their reproduction with the minimal means and equipment required, could give an idea on how materials for painting were prepared and did work (21). According to De Mayerne, oil varnishes and spirit varnishes, retouch varnishes and thickened oils, were included in the category of varnishes. No matter how purified the resin, a varnish yellows with time even when kept in its container (22).

The properties required of a final varnish were already formulated at the beginning of the seventeenth century. See: Portmann about blooming and compare with Toch's final varnish; the need of varnishing a painting for protection; the requirement for a varnish to dry well, to be light and transparent;



Oil Vehicles

the common final varnish (Hoogstraten, etc.) composed of Venice Turpentine, mastic, and turpentine, used also as retouch varnish instead of walnut oil; Venice or Strasburg Turpentine used for small paintings or as a retouch varnish by Van Dyck; mastic with or without a small amount of oil as final and retouch varnish, etc. The application of a retouch varnish should be regarded, according to De Mayerne, only as a measure to bring out the full tone of the colors before the very last retouchings. A small proportion of oil in the retouch varnish or final varnish assists ease of application (23).

II. Paints and techniques

A painter knows what to expect from a given pigment, vehicle, or paint. He will never expect a set of oil colors to have the same consistency, the same drying rate, or to perform in the same way (24). Nevertheless it seems that the basic requirement of a paint, to work well when used, has been almost forgotten today. For instance, the American Commercial Paint Standard CS98-62 covers only minimum requirements for oil paints: linseed and/or poppy oil as vehicle (method of refining not specified;) pigments of good grade, labeling being the one established through usage; driers (0.1% cobalt or 0.2% manganese calculated as metal, on the weight of oil;) inerts and fillers (not to be used as extenders, reducers, or diluents) and bodying agents (metallic soaps and/or refined beeswax) in order to produce consistency and prevent settling of pigment. These additives are practically useless in case of a paste of soft consistency, that is to say containing a larger proportion of vehicle (25).

As precaution against separation of pigment and vehicle in tubes which are stored, oil colors are left to mature after grinding and before tube filling. However, some pigments are more prone to separation than others, and if excess oil is found on opening a tube it may be removed by means of blotting paper. A homogeneous and softer paste may be also obtained, without removing the oil, by mixing thoroughly the color with a palette knife before use (26). Pigments and vehicles of good quality are available from reliable suppliers to both manufacturer and artist. Almost any medium and formula may be duplicated with a studio equipment, it being of the same quality if not better than many trade products (27). Since commercial reasons were of no concern to us, only a basic equipment and basic knowledge of chemistry were required for the correct formulation of paints, our purpose being the use of dependable materials and an understanding of their inherent properties. Oil absorbtion depends upon origin of pigment, washing, warming prior to grinding to eliminate moisture, vehicles and additives, and qualities sought for in the paste (28). Basic tests for determining purity of pigments have been already described about 1860 by Forni (29). It is worthwhile noticing that ultramarine mixed while painting with lead white and 2% drier is more permanent to light; madder lake difuses slowly from the substratum of aluminum hydrate and only a small proportion of lead white mixed in during work stops the process (30). Thixotropy is an inherent property of pigments such as artificial ultramarine, lead white, brown ochres. It may be produced in others while painting, by a drop of strong drying oil cooked with lead oxides. Once an optimum degree of grinding for a specific pigment and a specific purpose is accepted, i.e. stiff (underpainting,) medium or soft (overpainting,) buttery or long and stringy, a quick initial setting is insured by the proper vehicle: "Commom ceruse contains 50% whiting. Grind it very finely in linseed oil," or "[Blue] ashes and smalt must be mixed [i. e. tempered] lightly on the palette with walnut oil," specifies De Mayerne (31). The working properties of lead white ground in linseed or walnut oil can not be replaced by any other vehicle. In fact, zinc white ground in linseed or walnut oil is thixotropic and does not show its usual drawbacks; it works as well as lead white, being somewhat slower drying. Although the drying curve of walnut oil is similar to that of poppy oil, written evidence as well as numerous paintings show that it works well. It can be obtained almost colorless and drying faster by simple washing and exposure to sun. The thixotropic properties of a paint ground in linseed or walnut oil can not be duplicated by the use of safflower, sunflower, or soy oils, present in certain brands of colors (32). Our experience, as well as communications from various Colormen, show that the vehicle should be of low acidity or almost neutral (33).

APPENDIX. Recipes and practical procedures

In addition to the general observations we have given, we quote the following procedures and recipes for general, all-around purposes.

Heat-processing of oil. Linseed or walnut oil is boiled in a new earthenware or glass vessel filled one half. Water or other ingredients may be added (boiled oil partially polymerized.) Litharge and other driers are suspended in a bag (oxidized oil, e. g. Lebrun's siccative and fat oils.) When cool, let settle and sunbleach the oil poured in a glass bottle. Filter it. Heat treatment with air admitted of walnut and linseed oil produces a vehicle whose dried film has more durability and reduced tendency to after-yellowing. It is more viscous and may be substituted for other forms of oil during preparation of any vehicle. A reliable medium contains heat-processed oil diluted to suitable consistency. It will not wrinkle, turn yellow, or crack. In concentrate form it imparts a good gloss to the colors. A drop of strong drying oil is recommended for glazes with slow drying colors. Walnut or linseed oil boiled with water and drier is a versatile, general purpose medium. Use of a thinner is generally unnecessary as it is thixotropic and the mixing with oil colors results in an increase in fluidity. Moderate impasto may be applied when a small proportion of medium is added to colors. Heavy impasto and texture effects are easy to achieve as the paint stays put without levelling out. The medium is suitable for glazing when a greater proportion is added.

Red lead is a good example of pigment preparation. De Mayerne remarks: "If you extract the salt from the minium by washing it with distilled vinegar, the remainder does not fade and dries very well." Saturnine red (mine orange) is prepared by washing the minium in vessels of distilled water which is changed every fortyfour hours, till the surface is free from extranous matter, and the color ceases to blacken at the edges of the vessel. It is afterwards purified with wine spirit (34)

As for varnish making, the pulverised mastic resin, warmed first to free it from moisture, is put into a gauze bag and hung in a wide-necked glass so that it hangs in the essential oil. Impurities remain in the bag. Church suggests to dissolve 14 parts mastic with 6 parts sand and 44 parts turpentine in

a double-boiler. Leave to clarify. Some Venice Turpentine or Stand Linseed Oil may be added to make the varnish less brittle.

References and footnotes

1 See S.C.Arteni, "Studiu asupra bisericilor dela Voronet si Arbore; traditiile tehnice ale picturii bizantine: pictura murala, icoane si manuscrise, dupa manualul dela muntele Athos," Buna Vestire XV 3-4 (1976), 65-100, for grounds in byzantine panel painting.

2 S.C.Arteni, M.Sanchez-Posada, "Grounds for Oil Painting. A Survey of Materials," Proc. I.S.F. 14, 1978 (Correggio: SIRAI, 1980), p. 71-77.

3 De Mayerne MS (British Museum, Sloan No. 2052) in E.Berger, trans., Beitrage zur Entwickelungsgeschichte der Maltechnik (Munich: Callwey, 1901-1912), IV.

4 S.C.Arteni, "Istoria artei crestine in Europa" (unpublished radio commentaries, Radio Vaticana, 1974-1976.)

5 S.C.Arteni, "The Construction of a Painting," Proc. I.S.F. 14, op. cit., p. 62-64.

6 S.C.Arteni, "Space, Color, Medium," Ibid., p. 159-180.

7 S.C.Arteni, "A Century of Romanian Painting: 1877-1977" (unpublished paper, Proc. A.R.A. 3, 1978.)

8 S.C.Arteni, "Pallady. Romanian Painting in Europe" (unpublished paper, Proc. A.R.A. 2, 1977.)
S.C.Arteni, "Aesthetic Problems of the Paint Layer: Moldavian Wall Painting, Easel Painting and Illumination in Relation to Modern Oil Painting in Romania" (unpublished paper, Proc. A.R.A. 4, 1979.)

9 S.C.Arteni, "Les materiaux pour couleurs à l'eau et pastels dans le manuscrit du docteur Turquet de Mayerne," Proc. I.S.F. 14, op. cit., p. 135-138.

10 S.C.Arteni, "Pacheco. Original Extracts on Distemper, Tempera, and Illuminating Materials," Ibid., p. 61-62.

11 S.C.Arteni, "Inquiry into the Nature of Oils and Varnishes used in the Low Countries," Ibid., p. 113-124.

12 S.C.Arteni, "The Manufacture of Oil Vehicles for Painting Purposes," Proc. I.S.F. 13, 1976 (Modena: Artioli, 1976), p. 5-15.
Volpato MS in M.P.Merrifield, trans., Original Treatises on the Arts of Painting (New York: Dover, 1976.)

13 S.C.Arteni, "Notes on Artists' Materials," Proc. I.S.F. 14, op. cit., p. 139-153.
See particularly the Le Begue MS (1431) in Merrifield, op. cit., p. 303: "Si vous voulez appareiller oile pour destremper toutes manieres de couleurs. Prenez chaux vive avec autant de ceruse comme est de loile, puis metez au soleil et ne le movez jusques a ung moyt ou plus tar quant plus y sera, et mieulx vaudra, puis le colez et gardez tres bien loile, et de celle oille gardee et ainsi preparee, povez destremper toutes couleurs ensemble et chacun par soy."

14 S.C.Arteni, "The Strasburg Manuscript, a Compendium of Van Eyck's Materials and Techniques," Proc. I.S.F. 14, op. cit., p. 127-134.
See also Berger, op. cit., p. 182 (Illuminierbuch) and p. 196 (Italian varnishes;) Merrifield, op. cit., p. 489 (Bolognese MS.) The term boiled oil is applied to the modification of linseed oil by heat treatment. On the small scale, direct heating is used. The oil is heated to a moderate temperature to coagulate the break, it is then allowed to cool and settle, and the clear oil is decanted off for the preparation of Stand Oil. This may be superseded by the use of alkali-refined linseed oil. The traditional recipes for boiled oil recommend heating for one to two hours. The traditional Dutch Stand Oel is heated in open pots for six to eight hours according to the viscosity required, at from 260°C to 300°C. For mordants see the Marciana MS (sixteenth century) in Merrifield, op. cit., p. 621: "L'olio di lino si purifica cosi: fallo bolire al fuoco tre o quattro hore con l'acqua, poi lascialo riposare poi separalo dall'acqua."

15 Merrifield, op. cit., Introduction, p. CCXXXIV.

16 S.C.Arteni, M.Sanchez-Posada, "The Materials and Techniques of Spanish Masters," Proc. I.S.F. 14, op. cit., p. 57-61. Rubbing down or scraping the dried and glossy surface of a picture with a knife, sandpaper, or pumice stone, as related by Armenini, Boschini, and Pacheco, was done in vue of giving it a tooth even when sanded to a smooth finish. Thus the underpainting will have sufficient grain to take the new paint from the brush and to make it adhere well. To remove the matt appearance thus obtained, rub on a little oil (or a slow drying retouch varnish) with the finger and wipe off with a rag. If a picture has dried dead in parts, oiling out should be done in the way already described, all excess of oil being wiped off before the next layer of paint is applied. Oiling out restores the full tone of colors and provides a rich wet ground for further wet-in-wet painting.

17 See S.C.Arteni, "Notes on Romanian Painting Techniques," Ibid., p. 79-80, for the use of essential oils.

18 S.C.Arteni, "Amber and the Italian Varnish," Ibid., p. 64-65.
When heated for a short time to the point of fusion i.e. 310°-320°C, amber is altered and becomes soluble in turpentine, oils and other solvents. After fusing at 150°C, sandarac is readily soluble in oil. For amber varnish see the Paduan MS (sixteenth-seventeenth centuries) in Merrifield, op. cit., p. 689: "Vernice d'ambra. Piglia grassa terbentina, fala bollire per ¼ d'hora, e ponili del ambra sul marmo ben in polvere fata, e falla bollire per mez'hora sin che l'ambra sia liquefata, levala dal fuoco, e subito fredda, divera dura, volendola adoperare bisogna aiutarla con l'oglio di terbentina, accio si liquefaccia, e fala un poco scaldare per maneggiarla bene, avvertendo che quando e calda di farla passare per un panno et quello che passera sara il buono, applicandolo con pennello overo con la mano ben calda. Bisogna avertire che tutta questa compositione, si deve lavare nel acqua calda dopo d'haverla ben colata accio sii ben netta e purgata."

See Le Begue MS, Ibid., p. 313, for the usual sandarac varnish: "A faire bonne vernix liquide pour paintres. Prenez glasse aromatique [i. e. sandarac] qui est obscur par dehors et par dedens quant on le brise il est clair et luisant a maniere de voirre et en mettez une partie en un pot neuf qui soit assis sur la bouche dun autre pot et soient bien lute ensamble, et le pot denhault bien couvert que fumee nen ysse et soir percie au fons et faites feu dessoubz, tant que vous santez que la glasse sera fondue. Puis prenez oile de lin, ou de chanvre, ou de noix deux parties, et le chauffez au feu petit a petit et ne li laissiez pas trop chauffer, puis le getez par dessus avec la dicte glasse, et faites bon feu et le faites bien boulir par lespace dune heure, et gardez tres bien que la flamme ne la touche. Puis lostez du feu et mettez en vaissel cler et net, et quant... voulez vernicier si prenez de ceste liqueur et la tandez dessus la painture a voz doiz; car se vous le fasiez du pincel il seroit trop espez et ne pourroit secher...."

19 S.C.Arteni, "Alchemy and the Art of Painting in Oils," Proc. I.S.F. 14, op. cit., p. 135.

20 J.S.Mills, R.White, "Natural Resins of Art and Archaeology, their Sources, Chemistry and Identification," Studies in Conservation 22 (1977), 12-31.
For shellac varnish see the Paduan MS in Merrifield, op. cit., p. 689-691: "Altro secreto per fare la vernice vera d'India. R. Gomma lacca, et oglio di spiga tutti neti e puri, l'oglio bisogna che sia netatto dalla sua grossezza con tanto di letargirio d'oro, quanto di oglio, e questo bisogna far passare per un vetro per distillatione, e si torna a riposare, sino che sia ridotto chiaro, e passato due volte si piglia un altra bozza... e per ogni quattr'oncie di spiga, si piglia un'oncia di gomma lacca... si mette sopra foco di carboni, e si fa tanto bollire sin che si muta il colore, e diventi come mele... si mette una goccia sopra un cortello, e restando tutto unito, e buono...."
See also De Mayerne in Berger, op. cit., p. 140: "Vernix des Indes. Lacque. La Gomme lacque se dissoult tant seulement dans huile d'aspic, s'estend avec le doigt sur ce qui on veult et quelques besoigne que ce soit...."

21 S.C.Arteni, "The Medium and Grounds of 17th Century Flemish and Dutch Pictures of Flowers," Atti del Convegno sul Restauro delle Opere d'Arte Firenze 1976 (Firenze: Polistampa, 1981), p. 59-62.
S.C.Arteni, "Poppy Oil Vehicles," Proc. I.S.F. 14, op. cit., p. 125-126.

22 M.Havel, "Un élément nouveau dans la couche picturale de la peinture moderne: le vernis à retoucher. Un exemple: le vernis à retoucher Vibert," I.C.O.M. Report 19/72/10, Madrid (1972).
See Cennini for the use of a preliminary varnish composed of either white of egg (chap. CLVI: "Come in corto tempo puoi far parere invernicata una pittura... togli chiara d'uovo... ne da' a distesa sopra i tuo' lavorii;... Questo cotale invernicare ama molto le figure distagliate, o de legno o di pietra....") or parchment size (chap. CXI: "Colla la quale e buona a temperare azzurri e altri colori... E dove avessi campeggiati colori che non fussero stati ben temperati, da' una man di questa colla... che gli puoi vernicare a tuo' posta se sono in tavola....") to be applied in first place over egg tempera.
See De Mayerne in Berger, op. cit., p. 140 and p. 318 for the use of white of egg as preliminary varnish: "Le blanc d'oeuf soit reduit en eau, en l'agitant avec un baston couppé en quatre, et renversé par le bout en patte d'oye. Il se fera premierement une escume, laquelle dans peu de temps se resoudra toute en eau... Du Blanc d'oeuf sur labeur a Huyle. Il mange et gaste avec le temps les couleurs et si attache si opiniastrement que encor que vous lavies le tableau souvent encor y en reste-il quelque chose."

23 S.C.Arteni, "Imaginile sacre si spiritul unei tehnici," Buna Vestire XIII 3-4 (1974), 131-163.
See also Havel, op. cit.
X. de Langlais, La technique de la peinture à l'huile (Paris: Flammarion, 1969), p. 385 (one part Chios mastic to three parts rectified turpentine,) p. 195 (amber varnish suggested by Thiele: pour chloroform over pulverised amber, cork well and leave for two or three months; then let the chloroform evaporate and dissolve the swollen amber in boiling turpentine,) p. 402 (an interesting fixative for charcoal or pencil drawings on paper: take ten grams bleached shellac and 100 grams alcohol at 90°-95°, mix, shake well the bottle; it dissolves in about twentyfour hours and is clarified in a few days; eventually add 1/3 part alcohol to one part concentrate fixative; charcoal drawings on canvas, used as guide before painting in oils, should never be fixed.)

24 S.C.Arteni, "The Notes of De Mayerne on Artists' Oil Colors," Proc. I.S.F. 14, op. cit., p. 103-112.
See Eraclius (before the thirteenth century) quoted by Le Begue in Merrifield, op. cit., p. 233: "De pratica generali in movendo omnes colores. Sciendum autem est quod omnes colores cum aqua clara moli possunt, si postea exsiccari permittantur, ut postea glarea, vel oleum, vel aqua gummata, aut acetum, seu vinum, necnon cervesia, quomodo misceantur aut temperentur."
See also the Paduan MS, Ibid., p. 667: "Per far asciugare prestamente la lacca, indico, e negro di fumo. Macinati a olio, si piglia polvere di vetro ben pesta, e macinati sottilmte, poi s'incorpora con li sudti colori, rimacinandoli di nuovo, e cosi in spazio di ventiquattro hore s'asciugheranno."

25 S.C.Arteni, "Experimental Oil Painting 1973," Proc. I.S.F. 14, op. cit., p. 78-79.

26 S.C.Arteni, "Wax and Other Materials," Ibid., p. 109.

27 S.C.Arteni, C.Y.Jeanson, "Properties of Basic Lead Carbonate Ground in Various Vehicles," Ibid., p. 85-101.

28 S.C.Arteni, "Notes on Some Formulae for White Oil Colors," Ibid., p. 77-78.

29 U.Forni, Manuale del Pittore Restauratore (Firenze: Le Monnier, 1866.)
See J.Blockx, Compendium (Anvers: J.E.Buschmann, 1922), p. 58, p. 80, and p. 84, for purification of pigments: "Les couleurs artificielles doivent être

purifiées par des lavages répétés, jusqu'au point ou les dernières eaux n'accusent plus de réaction acide ni alcaline, au contact du tournesol... surtout... lea couleurs preparées par voie humide, et qui n'ont pas été calcinées. Les couleurs naturelles sont purifiées par dilution, c'est-à-dire qu'apres les avoir pulverisées, on les delaie à diverses reprises dans une quantité appropriée d'eau pure, en decantant chaque fois après agitation, pour séparer les parties plus légères. Ce traitement élimine la plus grande partie des corps étrangers... et leur communique plus de finesse....
"Les ocres... pour servir utilement à la peinture artistique, il faut qu'elles aient été convenablement purifiées par dilution et séchées lentement à l'air libre, sinon elles montent de ton pendant des années.
"La terre verte et la terre de Sienne naturelle comme d'ailleurs les autres terres et ocres devraient toujours, après epuration et pulvérisation, être longtemps exposées à l'air libre, en couches peu épaisses et à l'état humide. Ce traitement leur communiquerait la teinte exacte qu'elles acquièrent par le temps lorsqu'elles sont broyées à l'huile."

30 M. Hours, S.Delbourgo, A.Stoebner, "Alterations physico-chimiques de la couche picturale. 1. Comptes rendus de l'enquete auprès des différents laboratoires: altérations apparentes de la couche picturale et leurs causes probables. 2. Etude experimentale du laboratoire du Musée du Louvre sur la laque de garance," I.C.O.M. Report 67/16, Brussels (1967).

31 S.C.Arteni, "Emulsions et Mediums," Proc. I.S.F. 14, op. cit., p. 88-90.

32 S.C.Arteni, "Two Retouching Media," Atti del Convegno sul Restauro delle Opere d'Arte, op. cit., p. 63-65. S.C.Arteni, "Inpainting Media," Proc. I.S.F. 14, op. cit., p. 153-154.

33 See A.Clarke, P.Rylands, eds., Restoring Venice: the Church of the Madonna dell'Orto (London: Paul Elek, 1977), for a full discussion of Tintoretto's technique and materials. See also C.Ferrario, La Tecnica della Pittura ad Olio (Rovereto: Teolongo, 1950.)

34 See S.Audemar cited by Le Begue in Merrifield, op. cit., p. 142: "Take water and wine, so that the third or the fourth part may be of wine, and put it into a horn with the minium, and mix it well, stirring it. Afterwards let it rest. When it has settled and is fallen to the bottom, throw out the water and wine...."

MATERIALS OF THE ARTIST: THE SURVIVAL OF TRADITIONAL GROUNDING AND PRIMING METHODS FOR OIL PAINTING

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SUMMARY

There is nothing on which the preservation of an oil painting so much depends as on the quality of the support and ground. The various operations traditionally found most successful in preparing grounds are described, and further compared with data communicated by contemporary manufacturers of artists' canvas.

In this account of the materials adopted for grounds, it is to be observed, that it has not been our intention to give a complete survey of all processes employed, but merely to provide the reader with enough evidence regarding a traditional practice, whose particulars are still well preserved by today's industry. Technique means materials in action. There is nothing on which the preservation of an oil painting so much depends as on the quality of the support and ground. For example, the use of linen caused a change in the nature of the ground, which on canvas must be composed of elastic and flexible materials, not liable to crack or be detached when the canvas is rolled up. Obviously, the subject of the grounding and priming of panels and canvases forms an important part of most of the old treatises. Perhaps the only technical process which has survived almost without change is the method of preparing grounds. The layer found under the colors of seventeenth century paintings is nearly, if not precisely, the same as that often employed by the painters of the present day. In the ensuing pages we have endeavoured to present in as simple a manner as possible the various operations traditionally found most successful in preparing grounds. These processes have been thoroughly tried out, and compared with data communicated by some of today's most respected manufacturers of artists' primed canvas, cited in the footnotes.

De Mayerne describes the careful manipulations required in sizing:
"After stretching, and before priming the canvas, it is necessary to eliminate all roughness, knots, and threads, by means of pumice stone; then, to size...." (1)
"Firstly apply strong size, by sprinkling it with the brush, then levelling [smoothing down] with a spatula knife; let dry overnight... It splits." (2)
"...the canvas is sized with <u>a not too strong glue size</u> made from leather scrapings, otherwise it cracks." (3) [Emphasis is ours.]
"After stretching your canvas, size it with one layer of size; when the glue is dry, level with pumice stone; then apply a second layer of size. Let dry...." (4)

He says further for a single-primed canvas:
"Canvases must first be sized with calf or goat-skin glue; the whole artifice consists in this. <u>For if the glue is too strong, the canvas easily splits and tears.</u> After sizing, lay it while still damp on the marble slab, flatten with the muller all joints and knots; then let it dry. Then prime with lead white and a little umber. One priming is sufficient, but two layers make the ground more even." (5) [Emphasis is ours.]

For double-primed canvas he directs:
"First it should be sized with strong size [but see the warning above] applied with a knife by making it enter the weave of the said canvas; let dry. Then, take bolus ½ lb., umber 2 ozs., grind with oil and prime with a large brush or with a spatula, evenly. Let dry. Then take off all knots with a knife, by scraping, and level with pumice stone. Finally, prime with lead white and umber, i.e. lead white 1 lb., umber 1 oz....Instead of umber take yellow ochre or burnt red earth." (6)

De Mayerne explains next:
"The best priming is lead white (Plumbum Album) and some ochre, minium, or other competent color. However, it must be observed and known that minium, verdigris, or lampblack, are like poisons which kill the superimposed colors... This priming will be good at last, because, if one wants to economize, the first layer may be made of ochre and the other as above. The second layer with lead white and charcoal black. When priming, the first layer must be applied with the knife...when dried, all knots in the canvas should be cut off with a sharp knife and then it should be pumiced." (7)

He adds about treble-primed canvas:
"From the primer Wallon, in London. After stretching your canvas, size it with glue of scraps of leather or size, which should not be too thick (supposing that firstly you have cut off all loose threads.) When the sizing is dry, prime lightly with brown-red or dark English red. Leave to dry. Level with pumice stone. Then prime with a second and last coat of lead white, carefully chosen charcoal, small coals, and a little umber, that it may dry more quickly. A third layer may be applied, but two are sufficient." (8)

The priming method recommended by Blockx is recorded by De Mayerne as supplied by the same primer Wallon:
"He told me he primed a few times without sizing, by soaking firstly the canvas [in water] then applying the first priming [while it was still wet,] leaving it to dry, and levelling with pumice stone when dried. Finally, he applied the second layer, and even the third as above. The canvas is very flexible and never splits. Mr. Elie Fettz, painter of Constance, also tried this method, but a great amount of color has to be used."(9)

De Mayerne notices the properties and working qualities of the various materials employed:
"Burnt ochre, reddened on the fire, is good for priming. The brown-red, purified on the fire, becomes darker, and dries very well." (10)
"Common ceruse contains chalk, up to half." (11)

He explains next:
"Chalk, mixed with a little ceruse or lead white and oil, dries very well, and does not scale off." (12)

Lebrun remarks:

"Umber is of no use in priming, for it imbibes [strikes through] the colors laid on it...." (13)
"The longer the canvas has been primed, the better it is, for the colors laid on it become brighter." (14)

Bolus, according to Lebrun, is potter's earth (white bolus, or China clay,) which gives a smooth surface if pumiced. A small proportion of chalk or white bole in the ground ensures slight absorbency: so the rule "paint fat over lean" is respected, starting from the very first layers of the picture. Note further that no essential oil is mentioned as thinner for the priming composition.

Rubens' grounds on canvas vary from light brown to light grey. They usually consist of two layers: a first priming coat based on ochre, lead white, and chalk, ground in oil, and a second top coat of lead white and vine black, ground in oil (15).

It is of interest to compare these accounts with the practice of Italian, French, and Spanish painters. Volpato also gives similar directions for sizing and priming:
"...I use simple glue... which I lay on twice, pumicing each coat when dry, that the canvas may become even. Afterwards, I apply the priming, ground in linseed oil, and all earth colors are good for this purpose... I use terra da bocali, red ochre, and a little umber, ground [powdered] finely and mixed for a short time, over the fire, with linseed oil, without grinding. I apply it with the spatula over the canvas, and when dry and pumiced, I lay on another coat, but this must be ground." (16)

Lebrun's ground is identical to those mentioned above:
"Canvases... are primed with potter's earth, yellow earth, or ochre, ground with walnut or linseed oil. The priming is applied with the spatula knife or palette knife to render it even." (17)

A sort of half-chalk or emulsion ground is also suggested by Lebrun:
"To prime a canvas so that one may paint on it the same day: grind together parchment glue and oil priming, and prime quickly the canvas with this. It hardens directly, but it may scale off when the canvas is rolled up." (18)

Pacheco recommends three layers of priming:
" I consider as safe, a weak glue size made of scraps of leather gloves. A few coats of it should be applied onto the canvas, when the size has cooled. It should then be carefully levelled with a spatula, to fill the weave of the canvas. When dry, it should be pumiced, and next, primed...
"The best smooth priming is that clay used in Sevilla, finely ground to powder and tempered [mixed] on the slab with linseed oil. An even layer of priming is applied with the knife. When dry, this is levelled with pumice stone... the second layer, which makes the ground more even and covering, should also be smoothed [levelled] with the pumice stone, when dry, in order to receive the third layer, to which some lead white may be mixed in with the clay, to give more body... One can prime without sizing... although the weak size makes the ground smoother." (19)

Pacheco notes that some painters prime with red earth ground in linseed oil, over a coat of size and sifted ashes, while others use lead white, vine black, and minium, ground in linseed oil, over a gessoed canvas. It is noteworthy, that up until modern times, the custom of using gesso grounds on canvas was never entirely abandoned in Italy (20).

According to De Mayerne, for the preparation of panels for oil painting, an oil priming is applied over a white gesso ground:
"On wood. Ground chalk, apply with size; i.e. glue ¼, water 2 lbs.; dissolve, and when the whole is melted, add as much chalk as serves to make a not too stiff paste; then smooth down evenly with a knife. Next, apply lead white and umber ground in oil." (21)

Pacheco gives a similar description:
"On panels... apply not very strong parchment glue size, to which two or three crushed heads of garlic are added. After tempering the gesso grosso unslaked and sifted, apply three or four coats of it, taking care that each one be dried, and the irregularities flattened; the gesso sottile is then tempered with size though not too strongly, and five or six coats are applied with it... when dry, it is scraped smooth;... a color is prepared with lead white and Italian Umber, not too dark; this priming is ground and tempered with fresh linseed oil, and a coat is evenly applied over the whole panel." (22)

Garlic juice and oxgall are used as wetting agents. Pacheco advises adding them to the first sizing of walls, prior to their preparation for oil painting:
"Apply a coat of hot size made of scraps of leather gloves, with a small amount of oxgall or a few crushed heads of garlic...." (23)

Rubens used to apply a thin, pigmented, size coat, containing lead white, chalk, and animal black, over the white gesso laid on panels (24).

Only Vasari speaks of a coat of size applied with the sponge, between the gesso and the oil priming, for both panels and canvases (25). Where less absorbency is required, the gesso may be coated with either oil priming or size.

Such processes have been used for many centuries. Throughout this period slow change has taken place as new materials, such as new pigments (26), have become available, or new processes have been developed by the paint industry (27). With the advent of oil-modified alkyd resins and the development of acrylics, synthetic priming formulas became available (28). Later trends included a move to develop such water based acrylic primings. This can be attributed to a number of motivating factors: increasing cost, pollution reduction and easier waste disposal, reduced personal exposure to lead.

Permanency is what canvas is all about. Linen has the supremacy over all other canvas. For economy reasons, cotton tends to replace it, as oil painting conceived as a hobby brings about a lowering of professional standards. Unlike many commercial artists whose work is painted for reproduction and after that discarded, the professional painter is concerned with conditions which may have significance fifty or hundred years hence. Fortunately, if and when he is willing to pay the price, a good quality primed canvas is still available in the trade. The buyer is justified in knowing what formulation has been used in priming. Adhesion to the substrate, an important property of surface coatings, as well as the effect of extenders on adhesion, have not been studied in detail so far, although the paint industry has investigated aspects of part replacement of the pigment titanium dioxide by zinc oxide or extenders, resulting in a lowering of the practical

adhesion of the coating. A ready primed canvas should at least be worked between the hands to see that the priming adheres properly.

APPENDIX. Marouflage techniques

Marouflage is a technique similar to the procedure known to restorers as doubling or mounting. The advantage is that one may paint upon paper or thin canvas, although the support is rigid due to the panel or canvas used for mounting. The grounding may be applied in a single very thin layer. It is well known that a large number of French and Romanian painters of the past hundred years used such a mixed support. The first author currently uses rabbit-skin glue size as adhesive.

Marouflage to canvas

A Fine canvas marouflayed to canvas

1) Stretch a ready-primed canvas, the primed side towards the stretcher, or stretch a strong unprimed canvas. Apply a coat of size and let dry overnight.
2) Next day, apply a second hot size coat.
3) Soak a thin piece of unprimed canvas into the same hot size solution.
4) While the second sizing of the stretched canvas is still wet, apply the thin canvas onto the support, position it carefully, eliminate any air by pressing firmly with the palm of the hand and working from the center outwards, and press well the margins of your thin canvas which exceed the dimensions of the stretcher, against the edges of the support, by means of a wooden blade, such as a sculptor's tool.
5) Prime after drying.

B Paper marouflayed to canvas

1) Size your support (same as above) and let dry. It will become taut upon drying.
2) Cut your paper a few millimeters smaller all around than the dimensions of the support. The paper could be thoroughly wetted prior to mounting.
3) Put the paper face down. Size the back and size again the canvas support.
4) Apply the paper face up, and proceed as above. Press its margins against the support.
5) After mounting, the unsized face of the paper could be lightly sized. A thin priming coat could be applied, if desired.

Marouflage of canvas or paper to panels or cardboard

The procedure is the same as above. It is recommended to size both sides of a piece of cardboard, in order to prevent warping.

Grounding

A good semi-absorbent priming is the following, parts being by volume. Take one part Foundation White (lead white with a small proportion of zinc white, ground in linseed oil) or lead white stiffly ground in linseed oil, and mix this with one part fine marble dust well ground in raw linseed oil. A little extra marble dust is then ground into the paste to make it stiffer. A small proportion of vine black ground in linseed oil may be mixed in with the palette knife to give the priming a cool silver grey tint. Where a colored ground is required, the priming composition is colored with earth pigments. A thin coat of this is laid on with the brush or with the edge of a palette knife and the support left to dry. If a brush is to be used it is advisable to thin the composition with a small amount of turpentine. Tradition wants that the above was the ground of Guercino and the Carraccis.

The versatility of a marouflayed support permits the artist to apply a variety of grounding formulations, and consequently to use a variety of techniques, from water based to oil based paints. Ostwald and Lamb suggest a solution of 7% glue to 2% alum as a coating for rag paper meant to be used for oil painting. As an alum based ground is usually recommended for the preparation of paper, let us cite the traditional Chinese mode of preparation of silk for glue (distemper) painting, described by Mai-mai Sze in her 1959 The Way Of Cinese Painting:

> "In the summer months, use seven ch'ien [1|10 of a Chinese ounce, which is a little more than an ounce avoirdupois] of glue to three of alum. In the winter months, to one liang [one Chinese ounce] of glue use three ch'ien of alum... The alum should first be soaked in cold water until it dissolves. It should not be put into hot glue or the alum will cook... The first coat should be light. The second should consist of several layers of light coats. And the third should be very thin indeed... A solution of alum and water may be applied lightly for protection on the front and back of blue-and--green landscape paintings."

In case water based media are used, changes in their properties may be sought for. Chemicals, such as sal ammoniac - recommended by the Strasburg MS for acidifying and preserving a white of egg and gum medium - will not be commented here. There are numerous examples of the use of a thickening paste or gum in Turner's watercolors, which probably were the basis for the so-called watercolor megilp. This thickening makes the colors behave more like tempera or oil paint. Rice water or tragacanth gum may be used for such a purpose. Tragacanth gum swells to a gelatinous mass when soaked in water overnight. It can be shaken to a homogeneous consistency and used as such. It can also be boiled until a more fluid but still colloidal solution is obtained.

Footnotes and references

1 The De Mayerne MS [Sloane 2052, British Museum, London] in Ernst Berger, Beitrage zur Entwickelungsgeschichte der Maltechnik (Munich: G.D.W.Callwey, 1901-1912), IV, 248.

2 Berger, p. 258.

3 Berger, p. 252.

4 Berger, p. 338.

5 Berger, p. 116.

6 Berger, p. 252.

7 Berger, pp. 276-278.

8 Berger, p. 102.

9 Ibid.

10 Ibid.

11 Berger, p. 118.

12 Berger, p. 320.

13 M.P.Merrifield, Original Treatises on the Arts of Painting (New York: Dover

Publications, 1967), II, 813.

14 Merrifield, p. 821.

15 H. Von Sonnenburg, "Rubens' Bildaufbau und Technik. Bildtraeger, Grundierung und Vorskizzierung," Maltechnik/Restauro, 85-2 (1979), 77-100.
R.L.Feller, "Rubens' the Gerbier Family: Technical Examination of Pigments and Paint Layers," Studies in the History of Art (Washington: National Gallery of Art, 1973), p. 54 ff.
In regard to ready-primed canvases available in today's trade, the following details are worthy mentioning:
"All the canvases are glued with rabbit's skin glue except the nr. 3. The coating of the oil-canvases is a mixture of zinc white, chalk, linseed-oil and terpentine [sic.] The final coating is a paint of white lead, terpentine [sic] and linseed-oil. The absorbent canvases are primed three times with an emulsion of chalk and animal glue.
"The qualities nr. 3 and 66AC are coated with an acrylic primer. The expensive quality nr. 707 has 4 layers of zinc white and linseed-oil, and a final layer of white lead, linseed-oil and terpentine [sic.]" (Information in a letter to the first author from V.A.CLAESSENS of Waregem Belgium, July 8, 1980.)
"Elles sont enduites manuellement tout d'abord de colle de peau de lapin, puis d'une preparation a base de ceruse... Chaque toile est controlee par notre chef d'atelier, puis seche a l'air libre, sans aucune intervention d'infrarouge " (Information in a letter to the first author from BERGE of Wissous, France, April 9, 1980.)

16 Merrifield, p. 731.

17 Merrifield, p. 773.

18 Merrifield, p. 821.

19 Francisco Pacheco, Arte de la Pintura. Edicion del manuscrito original acabado el 24 de enero de 1638, ed. F.J.Sanchez Canton (Madrid: Instituto de Valencia de Don Juan, 1956), p. 75.
Many recent comments and reprints of Pacheco's work seem to be based on the 1866 edition by G.Cruzada Villaamil, which contains a large number of errors in printing, e.g. the short version published 1968 by L.E.D.A., Barcelona, we used in a previous paper. It is certain that such an error contained in the passage on canvas priming, may be the cause for the belief we have previously shared, that a half-chalk ground is described. However, as the present translation based on the 1956 edition shows, the formula refers to an oil primed canvas.

20 Linen and hemp canvas primed with gesso ground was still manufactured in 1974 by F.LLI MAIMERI & C., Italy.

21 Berger, p. 260

22 Pacheco, p. 73.
Gesso sottile is prepared from Plaster of Paris soaked for several weeks in excess water to prevent setting. It is used as final coat for grounds in panel painting.

23 Pacheco, p. 72.

24 P.Coremans and J. Thissen, "Composition et structure des couches originales en la Descente de Croix de Rubens - Etude prealable au traitement," Bulletin de l'Institut Royal du Patrimoine Artistique, 5 (1962), p.119 ff.

25 Luisa S.Maclehose, Vasari on Technique (New York: Dover Publications, 1960), p. 230.

26 Noteworthy mentioning is the disappearance of red grounds, based on red ochre. Red iron oxide provides good opacity, low solubility in water and adds high mechanical resistance to the paint film, at low cost.

27 Max Doerner, Malmaterial und seine Verwendung im Bilde, ed. Hans Gert Muller, 15th ed. (Stuttgart: Ferdinand Enke Verlag, 1980), pp. 73-97. The hand priming methods used by LUKAS Kuenstlerfarben und Maltuchfabrik Dr. Fr. Schoenfeld & Co., Duesseldorf, are illustrated on p. 94.
Thomas Brachert, "Zur Maltechnik Ernst Ludwig Kirchners," Maltechnik/Restauro, 87-1 (1981), 50-52. Kirchner used half-chalk grounds.

28 Anon., Artists Canvas by Fredrix (Lawrenceville: Fredrix Artists Canvas. Inc., 1977), p. 7. A variation to the traditional formula of hand oil primed canvas is to incorporate titanium dioxide for opacity, plus a small amount of mercury fungicide to prevent bacterial action. The sizing formulas are based on a highly refined grade of gelatin. Other formulas consist of oil modified alkyd resins for more absorbent surfaces, and also of acrylic primings.

THE SECRET OF THE MASTERS: HISTORICAL CONTROVERSIES AND HYPOTHESES

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SUMMARY

In following out instructions of former times, it is important to remember that the character and nomenclature of many materials have undergone change. This is useful for the purpose of giving an account of the methods of the artist's craft, in order to gain control over manipulations, and convey intentions properly, insuring the permanence of results.

To recognize old controversies or repetitions of long-buried disputes, such as the theory that the Masters had some closely guarded secrets, may improve the understanding of the general principles of the technically building up a picture.

I. The secret of the Masters

Accounts written by professionals or containing first-hand information should be preferred, e. g. the Athos Book, Theophilus, Cennini, the Strasburg MS, Van Mander, De Mayerne, Pacheco, Volpato, and Lebrun; other are innacurate due to compilation and translation without direct knowledge of the subject, e. g. Le Begue, Bolognese, Marciana, and Paduan MSS. In case of controversy on terms, recipes pertaining to the former are preferred. Important recipes are to be tried in almost the same conditions as indicated by the text. Old manuscripts should be always preferred: De Mayerne's MS, for instance, must be considered and accepted as truthful and exhaustive, as it gives almost all detail concerning painting techniques, e. g. even the washing of brushes. The aim was to find out whether the secret of the Masters does exist or not, by answering to five hypotheses:

1. The use of essential oil (Ziloty)

The Bolognese MS of the fifteenth century speaks only once about turpentine spirit (1). Spirit of wine and essential oils are introduced in final varnishes about the sixteenth century (2). The use of oil varnishes survives until the end of the seventeenth century (3). Spirit varnishes contain in most cases remarkable amounts of oil (4). In the seventeenth century the use of essential spirits is restricted to few pigments, merely blue, white and green pigments (5). This was a secret (6). Rubens is the only painter who ground pigments in essential oil prior to the admixture of Oil Vehicles (7). It is unimportant to know whether he used the solution of Venetian Turpentine in essential oil or more likely the essential spirit distilled from it: the fact is that he is the only artist of the time known to have thinned oil colors with considerable amounts of essential oil (8). It is thus demonstrated that essential spirits were not widely used even in the seventeenth century.

2. Emulsions (Berger, Doerner, Maroger, Laurie)

Size and oil emulsion serves in the seventeenth century for grounds (9). Gum arabic is mixed to oily ingredients, gums and resins, for gold size (10). Glair is to be found in a few Italian recipes, either to purify the varnish (11), or mixed to oil, presumably for miniature on paper (12). These are the few recipes similar to emulsions to be found in texts, which demonstrate that there is no real evidence for their being the secret.

3. Resins (Eastlake: amber; De Langlais: copal and Venice Turpentine; Doerner: mastic and Venice Turpentine)

The Strasburg MS was discussed elsewhere: the amount of resin to be mixed to colors does not surpass 15% of the binder. De Mayerne twice recommends spirit varnishes containing copal (13) or sandarac and mastic (14) to be used for thinning colors. Sandarac and mastic are the usual resins, while Venice Turpentine is preferred for retouch and final varnishes (15). The use of varnish in glazes and painting, though limited, was discussed elsewhere. Roughly the composition of varnishes was similar to modern painting media; as they were used in small amounts it may be assumed that they were not a decisive element.

4. Stand Linseed Oil or a similar product (Eibner, Laurie)

The light colored modern Stand Oil, a twentieth century product, could not be obtained because of the technical conditions it asks for; a thick boiled oil similar to it has been used for centuries in the Netherlands, but for house painting, not for pictures, as Mr. Roelof Roelofs, director of the Old Holland Artists' Colors Manufactory, communicated us; such an oil was rather dark. In workshops painters could approximate the properties of a thin Stand Oil by means of heat treatment.

5. Thick thixotropic media (Maroger)

Oils thickened by heating with lead driers are described by De Mayerne, i. e. the recipes of Cpt. Sallé and others, intended for varnishing iron, cloth painting, etc., not for pictures (16). English Megilp seems based on the so-called drying oil and varnish of Van Dyck, attributed to that painter by an eighteenth century writer (17). Van Dyck's comments on the desired fluidity of oil, as reported by De Mayerne, do not confirme this attribution (18). Instead, the thick varnishes of the Strasburg MS, made by dissolving resin into oil by means of heat, are of the consistency of modern Stand Oil, as experiments have shown us.

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The only material left are the Oil Vehicles, and in fact recipes show an extreme care in their preparation and use, either alone or mixed together. We must surrender in front of this simple evidence: oil painting means first of all prepared oil.

The traditional methods for preparing oil colors still do survive in Europe. In Spain the Bellas Artes S. L. oil colors are

manufactured according to Pacheco's recipes: raw walnut oil for white pigments, raw linseed oil for dark pigments, and both oils for the other pigments; the use of linseed oil cold-pressed and now also poppyseed oil to grind pigments by using porphiry rollers, is adopted by Old Holland Artists' Colors Manufactory. No other ingredients are employed by these two Colormen in their oil colors. Both confirmed the assertion we made elsewhere, concording with Taubes: to prevent gellifying of some pigments, e. g. madder lake, either while grinding or when stored, the oil should be purified so as to have a low acidity (adjusted for each pigment in the case of the quoted Spanish brand) or better be quite neutral (in the case of the Dutch brand,) the fluidity of the paste being thus insured without need of many further additives while painting.

II. Preparation of colors

> "Seule une belle matière peut être à l'échelle d'une belle idée." (Raoul Dufy)

Pacheco and De Mayerne may be said to have described the practice of oil painting in all respects relating to the most scrupulous preparation of the materials. Purity of pigments being indispensable, fine grinding and washing are essential operations prior to mixing the pigment with oils (19). After having been dried, the pigment may be ground in an Oil Vehicle. As the quoted authors observed, death of colors meant the yellowing and darkening of the Vehicle, which implied change in hue, caused by an excess of oil. It also indicates alteration by external agents acting on sensitive pigments, or chemical changes of pigments and color mixtures; also the washing off of the oil by excessive essential oil used as diluent, which exposes the unprotected pigment to atmospheric action, produces a dull surface requiring too much retouch varnish, and a brittle film structure (20). Accordingly in grinding (21):

- the quantity of oil must be kept down (colors ground stiff;)

- the Vehicle must be prepared and changed in order to obviate the sinking of the colored substance or the ultimate yellowing; thus the Vehicle was varied according to the properties of each pigment: oil absorbtion, light or dark hue, drying rate, opacity or transparence, etc.; this means:
    1. light and quick drying colors were ground in walnut oil;
    2. delicate and light colors for final painting were sometimes ground in poppy oil;
    3. all the others, especially the dark and slow drying ones, were ground in linseed oil;
    4. thickened oil was added to colors without body (22);

- some drops of a drying oil or a metallic drier were mixed in with slow drying colors used alone in glazing; fast drying protected the pigment and kept the gloss; often varnish or a thick oil was used in glazing to obtain transparence; for the same reason and not only to retain the desired beauty of a resinous glaze, the addition of varnish to colors sensitive to atmospheric agents was essential;

- delicate colors and glazes must be varnished as soon as dry to keep them protected (23);

- the operation for mixing tints required special care in order to conserve the purity of hue; mixed tints must be prepared on the palette with the spatula for greater homogeneity (24).

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Grinding signifies equal dispersion of the pigment into the Vehicle; tempering instead, is only mixing, either the dry pigment or the already ground color, with yet another Vehicle for the correct working consistency (25). Colors ground stiff by hand were tempered before use with:

- oil or an oily medium (with/without resin) diluted or not with an essential oil (26);

- a spirit varnish only (27);

- only an essential oil, by dipping the brush into it or by mixing drops of it with the palette knife into the colors; blues and greens were worked in this way; as they turn dull due to the essential oil, they need to be varnished as soon as dry (28); only Rubens used to spread his colors with the help of essential oil (29);

- for the same reason of purity of hue, blues were sometimes painted in gum water or size and then varnished; the color contained enough gum or size to be slightly glossy, otherwise varnishing would have changed its tone (30).

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The ultimate question of <u>embus</u> still remains unsolved. Pacheco stresses the difference between <u>lucido</u> and <u>lustroso</u>: the first term refers to blue painted with some essential oil; the second one describes a merely glassy polish caused by an abundant Vehicle; a painter is aware that a large amount of essential oil may be mixed with oil colors without impairing their gloss. Pacheco remarks that blue paint has to be applied thinly without stirring and mixing much the color (31). Oil ground, and Oil Vehicles require that a dead appearance be sought in a special way if desired. If the ground is not well dried, or if the first layer of the picture is not well dried, the overpainting turns dead; this happens by accident to painters in all times (32); when the first layer is well dried, this does not happen. In any case the picture needs retouch varnish for overpainting; if the <u>embus</u> was obviated, it is required only for wetting and to restore the tone of the color (33).

Varnishing the whole completed picture was not a widespread practice; De Mayerne describes varnishes intended for figures only (34); he specifies that varnishing the entire painting is desirable (35). Obviously, paintings which last a long time without varnishing, were glossy enough originally; final varnishing was intended only for protection and higher or equal gloss over the whole picture.

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If we now proceed to consider the Vehicles available, according to fifteenth century practice described by the Strasburg MS and according to the traditional seventeenth century technique described by De Mayerne and Pacheco, the result of examination of various methods of manufacture shows that at any rate two Vehicles, suitable for grinding and tempering colors, are used: a raw oil (see the recipes of Cennini and Le Begue quoted in

previous papers, with variations on these recipes) which, if exposure to sun and air is prolonged, may become a light or heavy bodied sunbleached and sunthickened Vehicle, and a boiled or heat processed oil, that is to say a fluid oil purified by means of heat (see the recipes of Eraclius cited by Le Begue and of the Strasburg MS) which may be obtained thicker by prolonged boiling or by an increase in the amount of drier, if any, used in its preparation. We express here a view which may seem different from what we have expressed before, but on revising the evidence available and after numerous experiments, it seems that cold-pressed, washed and sunbleached oil, and oil purified by boiling and further sunbleaching, are sufficient for artist's purposes. In both cases the Vehicle will be more consistent and drying faster than that used today for grinding colors. Recipes for purifying oil, which besides alkalies, driers or other substances, sometimes also use water and heat (thus producing purified, refined, light drying, and fluid boiled oils of various types including Lebrun's fat oil, according to variations of these methods) would produce much the same Vehicle as above, unless either longer exposure to sun and air (raw sunbleached through sunthickened oil,) or large amounts of metallic drier (cooked siccative or strong drying oil,) or prolonged heating (various boiled oils through light bodied and heavy bodied Stand Oil,) were used. Cennini describes both Vehicles: oil purified either by exposing it to sun, or by simply boiling it. Le Begue (36) recommends the addition of lime and lead white to oil exposed to sun and air. Thus his Vehicle will be faster drying and, if exposure to sun and air is long enough, the Vehicle will become similar to Rubens' varnish described by De Mayerne, that is to say an oil thickened over drier. The Strasburg MS and Eraclius (37) recommend purifying the oil by heating it with adsorbtive substances and alkalies, and continuing the treatment by exposing it to sun, the oil being mixed with drier. This Vehicle will also be more drying than Cennini's boiled oil.

A very simple method for purifying the resin prior to varnish making is employed in Italy (38).

Footnotes and references

1 Recipe 246 in Merrifield, II-512, 513.

2 Marciana MS recipe 401 for instance, in Merrifield, II-632, 633/ 628, 629.

3 Paduan MS, end sixteenth century, recipe 57, in Merrifield, II-672, 675. De Mayerne MS in Berger, p. 108 on Rubens and p. 184-188.

4 De Mayerne in Berger, p. 292.

5 Cf. Pacheco. Volpato in Merrifield, II-749. De Mayerne in Berger, p. 112 note / p. 108 / p. 118.

6 De Mayerne in Berger, p. 108 / p. 114 note.

7 De Mayerne in Berger, p. 332.

8 Ibid., p. 114: "M. Rubens. Aqua di ragia. Vidj."

9 Lebrun recipe 32 in Merrifield, II-821.

10 De Mayerne in Berger, p. 156. Cf. Roberson's Maroger Medium.

11 Bolognese MS recipe 262 in Merrifield, II-520. Compare to Van Dyck's method for purifying oil quoted by De Mayerne in Berger, p. 308-310.

12 Bolognese MS recipe 201 for lake in Merrifield, II-486.

13 De Mayerne in Berger, p. 334-336: "Vernix blanc de M. Feltz."

14 De Mayerne in Berger , p. 156.

15 De Mayerne in Berger, p. 156 / p. 292: "Verny siccatif." / p. 292: "Aultre siccatif." / p. 352 / p. 196 / p. 258: "Vernix d'Italie." / p. 268 / p. 312 / p. 318.

16 De Mayerne in Berger, p. 132 / p. 136 / p. 148 / p. 354.

17 Eastlake, Methods, etc., I-307, 308.

18 De Mayerne in Berger, p. 336.

19 De Mayerne in Berger, p. 272: "Toutes Couleurs, en se lavant, se peuvent diversifier. Les premieres qui se meslent exactement parmy l'eau sont les plus fines, les dernieres plus grossieres. Le blanc de plomb broyé premierement avec l'eau puis lavé et laissé rasseoir en decantant l'eau trouble, faict une residue qui est très belle et meurt moings que le fonds."

20 Eastlake, I-427, 428. De Mayerne in Berger, p. 112-114: "La mort des couleurs est quand l'huyle nageant au dessus se seiche et faict une peau qui noircit a l'air. Il y a quelques couleurs et les emaux entre aultres, qui ne se meslent pas aisement avec l'huyle mais vont tousjours a fonds sans se lier, et ainsi meurent facilement et noircissent." Eastlake, I-132. De Mayerne in Berger, p. 118: "Pour le bleu fault adjouster un peu d'huile d'aspic 2 ou 3 gouttes, ainsi la couleur penetre, ne reluit point et n'ayant pas de peau huileuse dessus ne meurt jamais."

21 De Mayerne in Berger, p. 100-136 / p. 184-188 / p. 190-193 / p. 195-201 / p. 216-233.

22 Eastlake, I-429. De Mayerne in Berger, p. 128: "Pour faire une huile espaisse fort siccative propre a mesler les couleurs qui manquent de corps, afin de leur en donner, pour ne tomber a fonds de l'huile."

23 Eastlake, I-469. De Mayerne in Berger, p. 268: "Indigo s'use a huile mais il meurt sans le vernix... un vert avec schitgeel obscur sur quoy fault passer le vernix et il dure." De Mayerne in Berger, p. 112: "Aurangé avec Vermillon... Quant on vernit ne change jamais... mais advises que vos couleurs soyent bien seiches avant d'y mettre le vernix."

24 De Mayerne in Berger, p. 112: "L'esmail ne doit estre mesle que fort legerement avec le blanc sur la palette. Car si vous le remuez beaucoup avec le couteau, il meurt facilement."

25 Borradaile, The Strasburg Manuscript, etc.

p. 55: "Colours must first be ground in the oil and then tempered with more oil, all pigments being ground and tempered to the consistency of a soft paste, neither too thick nor too thin...."

26 De Piles, Cours de Painture, in Eastlake, I-505: "Si l'on veut faire un portrait au premier coup il faut... faire an sorte qu'il y ait peu d'huile dans les couleurs; et si l'on y voulait meler en peignant un peu de vernis avec la pointe du pinceau, cela donneroit un moyen facile de mettre couleurs sur couleurs et de les meler en peignant sans les emporter."

27 De Mayerne in Berger, p. 156 / p. 334-336.

28 De Mayerne in Berger, p. 272: "Quand on travaille du bleu il fault... y mesler un peu de huile d'aspic ou de petrole et aussi tost qu'il est sec passer incontinent le vernix par dessus "
Ibid., p. 112: "Le vert ne meurt pas si quand on le met en oeuvre on adjouste sur la palette quelques gouttes de petrole ou d'aspic ou de Terebentine fort clair. Cela fait emboire la couleur et ce qui s'emboit ne meurt point."
Ibid., p. 108: "En travaillant en blanc ou en bleu si vous adjoustez quelques peu d'huyle d'aspic à vos couleurs elles ne mouront point, qui est un grand secret."
De Mayerne in Eastlake, I-431: "Quand on travaille avec le bleu, si on adjouste a la cendre d'azur un peu d'huyle d'aspic, la couleur ne meurt point."
Pacheco, Arte de la Pintura, about blue: "Y no tengo por malo mojar el pincel en el [aceite] de espliego cuando se va pintando, porque ayuda a rebeberse...."

29 Eastlake, I-528; De Mayerne in Berger, p. 114: "M. Rubens. N. B. Pour faire que vos couleurs s'estendre facilement et par consequent se meslent bien et mesme ne meurent pas comme pour les azurs; mais generalement en toutes couleurs, en peignant trempes legerement de fois a aultre votre pinceau dans de l'huile blanche de Therebentine de Venise extraicte au baing Marie puis avec ledict pinceau meslez vos couleurs sur la palette. Aqua di ragia. - Vidj."
Gentileschi mixed to colors some drops of Venise amber varnish, for flesh painting especially, "pour mieux estendre et adoucir et seicher plus tot," cf. De Mayerne in Berger, p. 112-114.

30 De Mayerne in Berger, p. 118: "Le Bleu peut etre couche à destrempe avec colle sur votre imprimeure a huyle frottée avec suc d'ail, puis estant sec appliqués un bon vernix subtil et fort siccatif."
Ibid., p. 336-338: Van Dyck.
Kuhn, A Study of the Pigments, etc., (1968) on Vermeer's "Diana and Her Nymphs," Mauritshuis, The Hague: "Blue paint, from the sky, upper edge: a semi transparent layer containing smalt in a protein medium...."

31 Cf. Pacheco: "Y pienso sin duda, que en esto principalmente - siendo el azul de buen color - consiste su perpetuidad, a lo menos, los que yo he gastado a la par de otros pintores, se rebeben y quedan lucidos y conservan su lindo color, muriendo a manos de los otros." Glazes are applied with ultramarine; if the first layer is too glossy, lustroso, it has to be scraped with the palette knife, washed over with a sponge and water and then repainted; Pacheco concludes: "...se ponga en una parte fresca - no vuelto a la pared - para que no se seque aprisa y se vaya embebiendo con la tardanza de secarse."

32 De Mayerne in Berger, p. 112: "Quand on met une seconde couche de couleur sur la première qui reluit, aussi tost qu'elle est seiche, incontinent la couleur s'emboit et ne meurt point."

33 Cf. De Langlais, La Technique, etc., part four.

34 De Mayerne in Berger, p. 184.

35 De Mayerne in Berger, p. 272: "Le Vernix faict fort bien passé par dessus tout un tableau; ainsi les couleurs se conservent et ne meurent point."

36 Merrifield, I-303.

37 Merrifield, I-233.

38 Cf. Forni, p. 281: "La mastice, essendo sempre impura bisogna prima purificarla, sciogliendola a bagnomaria nell'alcool assoluto. Poi si filtra per carta sugante o per cotone e si mette a seccare all'aria libera in un vaso di porcellana coperto da un cristallo, e si adopera polverizzata."

RESTORATION OBJECT IN SOCIOLOGICAL PERSPECTIVE

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SUMMARY

Herein there are viewed certain sociological motivations of various professionals engaged in restoration activities - of administrators, scientists, museum curators, art historians, restorers. Discussion aimed at causes of divergencies among all those as to the respective evaluations of methods, processes and final results.

The number of individuals and organizations determining the character and the scale of the modern impact on the monument have been growing during the process of developing the restoration work. In the past the client was directly in touch with the restorer and the sociological dialogue was held practically without third parties taking part. The client made an explicit statement of the required final goal of the restpration process which was naturally quite subjective. The transmission of information took place just once without any tangible interference. Irrespective of the methodological justification of the final objectives of the restoration, the objectives themselves were perceived by the two parties quite clearly. Their possible contradictions with the interests of society and science either remained unseen or seemed insignificant.
Therefore, the tasks of a purely technical or technological nature, but not of an ideological or methodical one, were the major problems in restoration. The more successful the artistic forgery of the original, the higher the appreciation of the professional skill of the restorer. The eye and the subjective aestheric requirements of the owner of the monument remained the decisive factor.
Nowadays, apart from the client and the restorer, many other people: administrators, chemists, physicists, biologists, art historians, archeologists etc. take part in the estimation of the monument, of its condition and the proposed stages of the restoration process. As a rule, their ideas of the final objectives of restoration are different, not to mention individual operations, materials and the necesary methods of examination. The transmission of information takes place repeatedly between scores of people by means of unsatisfactorily composed texts, which causes great interference and distortion in direct ratio to the number of secondary transmissions. As a resu lt a discordant chorus of many voices sounds instead of a subjective but distict sociological dialogue. Its participants are inspired by incompatible motives, the difference in training and t the collective traditions of the institutions by which they are employed.
The object of restoration has now become too multificeted under the intent looks of scores of people. It is viewed by specialists of exact sciences and archeologists as above all a priveless document of the irretrievable past and by virtue of this is subject to objective and critical reconstruction "elsewhere", purely speculatively and descriptively. Any invasion of modern elements with their evolutionary new aesthetic criteria is deemed unanceeptable. The status of the historical source and simultaneously the instruments of the scientific reconstruction is attributed to the object of restoration with considerations of an artistic and aesthetic nature having little if any effect on the evaluation of the particular status. However, art hislorians and restorers take a different view of this matter. The fragmentary remains of an object seems to them damaged and deprived of a cultural and historic significance. Under the pretext of the protection of the interests of the public and society as a whole they demand the restoration of the integrity of the artist's original intention and its artistic implementation alleging an absolute understanding of the latter. They attribute to the object of restoration the status of primarily work of art and place it highly within the system of valuable modern objects of art, allegedly more important to society than the documentary informational potential of the original distorted or camouflaged by restoration. As a matter of fact such restoration erests a barrier between the past and the present in the name of the interests of the latter interpreted in a peculiar way. It is explained by a hard necessity to return the monument to society in an intelligible form and purified from an excessive historical specificity which interests a small group of professionals alone.
In between these two poles there is a whole range of intermediate positions, indefinite decisions and evasive compromises. It may happen that monuments from one art collection undergo restoration based on different methods and then lose all features of the historical unity of their origin. And it cannot be otherwise of the practice permits the existence of several ideas of the final goal of the restoration process. For all these reasons the centre of gravity in the planning of restoration measures has begun shifting gradually from purely technological considerations to ideological ones, towards the theory of restoration however little it might be developed.
Restorers possess nowadays extensive technical capabilities which they do not always use for the good purposes precisely because of their disregard of the theory alleging usually that the prognostic and nomological capabilieties of the theory are far from the desired, although specialists of exact sciences estimate them somewhat higher.
In addition to the above - mentioned, it is necessary to note another level of the realization of sociological conflicts in restoration. The intergroup level was analysed above, but there is also an intragroup one. Advocates of the full imitation of the artistic characteristics of the original resort directly to the original to argue whether it is permissible to use modern synthetic polymeric materials for these purposes of not, whether it is necessary to imitate the image alone without regard to the pysico-mechanical structure supporting it or whether it is obligatory to re-create this structure bringing it as near to the original one as possible. And advocates of the conservati on method also debate on somewhat different subjects. They argue of the processes of the strengthening and cleaning, stratification of layers of different periods, methods of copying, for instance, with or without reconstruction elements. This is a methodological chaos which is explained purely sociologically, without reference to the fundamental factors of an economical or, more importantly, political nature.

Methodological principles and vacillating conceptions of the final objectives of restoration differ sometimes even within the same collective bodies and organizations with quite identical conditions of work and pay and under the same scientific direction. It is more noticeable in the sphere of the restoration of applied arts and archeological discoveries. Thus, whereas the principles of the restoration of monuments of monumental and easel painting have become more or less established and assumed a clearly defined aspect in the VNIIR, two quite different approaches to the artistic metal are being professed, and correspondingly an impressive stock of objects has now accumulated restored in accordance with two competing methods. Representatives of the two trends are sincerely convinced in their rightness, they are inspired only by considerations of an ideological and theoretical nature and subjective conceptions of how the past is to look in the eyes of modern man. Any considerations of a technological or economical nature play no role in this whatsoever. It remains only to guess which line of the two will in future be approved by society.
Similar examples in the activities of the most famous restoration institutions can be cited ad infinitum all over the world, inasmuch as the unsatisfactory state of the theory of restoration is approximately the same everywhere and only in recent years has begun attracting the attenti on of as yet specialists alone. The present-day task seems to lie in a detailed analysis of the development trends of the restoration work including hardly noticeable but in fact very influential sociological trends and a discovery of their effective corrective amendments without prejudice to the monument.
In brief, the contemporary situation in the field of the protection and restoration of cultural heritage is characterized, inter alia, by a complex of intricate socio-cultural contradictions between the participants in this common cause. The reason for them are inevitable distinctions as to sex, age, education as well as those less objective as to ideological and theoretical, group, taste and other subjective orientations. Some restorers, quite a few in number, are still inclined to noticeable anti-scientism and arbitrary aesthetization of their profession, others, fewer in number, rely on the instrumental capabilities of natural sciences and on the search for optimum nomological eriteria which would guarantee the historical authenticity of an object after its restoration.
As yet the complication of the structure of restoration services in many cases results in the growth of uncertainty, or, if you please, enthropy, in the estimation and prognosis of the final result of restoration and thereby in our understanding of culture of the past and even the present. Restoration, from a rare semi-exotic occupation of individuals, has grown into an interdisciplinary field of activity of large collective bodies and, consequently, made a necessity the systems of self-regulation and self-control to suppress the competition of ideological and theoretical and sociocultural paradigms. They are also necessary to eliminate the gap between the collective forms of modern scientific work and the traditionally individualistic way of thinking of the majority of restorers. This particular gap is one of the most serious sociological paradoxes of the contemporary period and in many instances influences the destinies of monuments, and this is the reason for its investigation and, as far as possible, neutralization.

THE ACHIEVEMENTS IN THE FIELD OF THE CONSERVATION OF MOVABLE WORKS OF ART IN CENTRAL AND NORTHERN POLAND AFTER THE YEAR 1945

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Summary

The present paper is the continuation of the reports from Venice, Zagrzeb and Ottawa concerning the conservation of movable works of arts in Poland. This time I would like to present /in a big summary/ the situation mainly from the point of view of the conservating studios, staff, education and their achievements in respect of technical and scientific research in the central and north Poland after the Second World War.

Before 1939 there were in fact three state studios; at the National Museum in Warsaw and Poznań and at the Warsaw Royal Caste. They employed about 1-4 persons. The Studio of the Conservation of the Works of Art stopped functioning at the beginning of the war. The studio at the National Museum in Warsaw, in turn was dispossessed of all its equipment, tools and materials in 1944. In case of the studio in Poznań, the situation was much better.
After the war it was extremely important for all the studios to start working because the war damages were great and so the need for the preservation of the works of art was urgent. However the task to complete the equipment, materials and the staff proved so difficult that there appeared the idea to create the central studio which would accumulate all the possible efforts in those days. Thus on the basis of this conception a new central studio was instituted in 1945. It comprised the Studios of the Conservation of Paintings, Graphics, Decorative Art and Sculpture and it was attached to the Chief Management of Museums and Monument Preservation, later transformed into the Studio of the Conservation of the Works of Art.

The studio began its work as a separate, individual state institution functioning according to economic calculations within the national plans. After the year 1955 it created 15 local sections and 6 subordinate departments. At the moment there are 35 specialistic studios within the Studio of the Conservation of Works of Art.

Simultaneously with the "centralistic" activity right after the war, some museums began organizing small conservating studios. In 1948 such studios existed in Maritime Province Museum in Gdańsk, Municipal Museum of the History and Art in Łódź, Mazurian Museum in Olsztyn, Wielkopolskie Museum in Poznań, National Museum and the Archeological National Museum in Warsaw and in the Main Registry of the Past Records in the same town. In 1960 there were many more; in Warsaw 3, Toruń 2, Bydgoszcz 1, Poznań 5, Leszno 1, Kalisz 1, Łódź 2, Lublin 1, Gdańsk 2, Szczecin 2, Zielona Góra 1, and Koszalin. This rapid qualitative development of the studios was stopped in the middle of the sixties in order to provide the studios with a more complete equipment and the materials.

A good accomplishment of the conservating studios, irrespective of its organization attachment, depends on a proper performing staff. This fact was clearly realized during the war and it gave the first premises for creating the basis for the schooling of conservation. The need for educating a new generation of the conservators was very urgent right after the war and in 1947 the first two-year Studio of the Conservation of Paintings was established at the Academy of Fine Arts in Warsaw. Later, in 1950 the Cabinet enacted a decree to set up two new departments of The Conservation of the Works of Art, one in Cracow and other one in Warsaw. On the turn of 1945/46 a new department of The History of Historic Monuments and the Preservations of Historical Monuments was created at the University in Toruń. In 1947, the department had its own studio and in 1952 The Department of Technology and Paintings Technics was established. The present Institute of the History of Historic Monuments and the Preservation of Historical Monuments exists within the frames of the Department of Fine Arts in Toruń.

In case of The Department of the Conservation of Works of Art in Warsaw it comprises four sub-departments; The Department of the Conservation of Paintings and Polychromed Sculpture, The Department of the Conservation of Sculpture and the Elements Sculpturally-Architectonic, The Department of the Conservation of Old Print and Graphics, and The Department of General Fine Arts. As for Toruń, the present Institute of The History of Historic Monuments and the Preservation of Historical Monuments which exists within the frames of the Department of Fine Arts, has its seven sub-departments; three of them purely theoretical, and four, the so called practical. The first three are; The History of Art, The Preservation of Historical Monuments and Museology. The practical departments are: The Conservation of Paper and Leather, The Conservation of Elements and Architectonic Details, The Conservation of Polychromed Paintings and Sculpture and the Technics of Fine Arts. The first three train the conservators in easel painting, old prints and book, sculpture and architectonic elements. The practical departments are known to educate conservators of painting, sculpture, details and elements of architecture, paper and leather

Both academies educate conservators of movable works of art. There are employed many specialist of highest competence from various different professions, e.g. art historians, museologists, chemists, physicists, microbiologists, artists, conservators, technologists of works of art; there are some professors among the teachers. The two academies are main centers of theoretical and applied development in preservation of historical monuments in the discussed region.

One should remember that the scholarly climate created by the teachers is well reflected in diploma works of the students, the works which are full of new and vital elements for our branch.

Scholarly achievements of the Warsaw center are especially transparent in preservation of paper, graphics, books, also metal; ethics and esthetics of preservation and research methods of the work of art. Contribution of the Toruń center to the preservation basically concerns stone sculpture, architectonic detail paper, leather, stained-glass but also technology of the works of art, and research methods of wall and easel painting.

However research and technical accomplishment are mainly due to the academic workers but one should also notice the contribution of Central Laboratory of Monument Preservation Studio,Main Archives,Material Culture Institute in Warsaw and Conservator Studios of Archeological and Ethnographic Museums in Łódź.

I chose to present only some examples of research and technical accomplishments in the discussed region of the central and nort -hern Poland from 1945 because complete listing would need much more space.It is worth to notice the method of evenly-rotary X-ray photographs for easel painting and autoelectrography for wall painting,also spectrographic analyses for both easel and wall painting /B.Marconi,P.Rudniewski et.al./The usage of chromatographic analyses for identification of painting binders /Z.Brochwicz and his associates/.Z.Brochwicz is also the author of several elaborations on identification of binders,tinctures,gilding materials and some painting techniques.Some new elements concerning preservation,retouching and doubling techniques are developed in M.Roznerska's works.Wood consolidation by synthetic resins solutions especially by epoxy resins and wood preservation in conditions of lesser pressure were scrutinized by W.Domasłowski and his associates.Evaluation of fungicidal means for wood preservation was performed by J.Ważny.R.Kowalik,J.Ważny,M.Husarska,E.Czerwińska and A.Strzelczyk are interested in problems of paper,parchment,leather preservation from erroding activities of microorganisms,and also in methods and means of disinfection.Methods of metal analyses and preservation elaborated by A.Kanwiszer,T.Dziekoński,L.Koziorowska contribute to new developments in this field.K.Kwiatkowski's scrutiny of the famous Gniezno door by radioactive isotopes should also be noticed.The method of stained-glass preservation by methyl polymethacrylate was the sphere of interest of F.Kwiatkowski and W.Domasłowski.Several elaborations of A.Buka, L.Kościszewski and J.Kruppe were devoted to pottery monuments.Significant output of W.Domasłowski and his associates /popularised not only in Poland/ concerns structural consolidation and elimination of layers sealing up stone surfaces in chemical way,e.g. by solution of hydrofluoric acid;further, stone preservation by solution of epoxy resins,finally technologies of stone mortars and fillers based on synthetic resins.

As I mentioned before because of the scope of this paper I could not venture to make a complete list of the achievements and also of those who contributed their work to these accomplishments.My aim /consequently realised from 1975 within a group devoted to theory and history of restoration/ is to present some basic informations about the history of the conservation of movable works of art in Poland.

Section 12

Care of Works of Art in Transit

Protection des Oeuvres d'art pendant le transport

THE EVALUATION OF A PACKING CASE FOR PAINTINGS

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SUMMARY

The packing case specification used at the Tate Gallery for paintings has not changed for several years. The many paintings loaned in packing cases fabricated to this specification appear to have been successfully protected as very few noticeable damages have occurred. An example of a typical packing case was therefore evaluated in a series of tests. An indication was obtained for the degree of vibration and shock that the paintings appear to have withstood. A temperature change half-time was determined and data was obtained relating relative humidity (RH) fluctuation and temperature change within the case. The results are reported in this paper.

INTRODUCTION

A packing case provides protection for an object by isolating it from the external environment. Within the case the various factors likely to cause damage must be kept to within the safe limits for the object being protected. To assess the performance of a case designed for a painting these limits must be defined. Useful limits have been determined for temperature and RH with reference to the museum environment (1). Theoretical arguments have been made by Stolow (2) regarding the control of vibration. However, the authors know of no assessment of the effects of vibration and shock on the structure of paintings.

For commercially produced goods the effect of shock is used to assess the fragility of a given product. A standard test (3) is to attach accelerometers to the object and to measure* the force of impact when the object is dropped from increasingly greater heights. The force (or more correctly the deceleration) experienced when damage is first observed is used directly as a measure of the object's fragility. For a mass-produced object several samples have to be tested but the results should then reflect the general fragility for this type of object. By comparison, paintings can be expected to exhibit a wide range of fragilities due to the variety of their structure, age and dimensions. This presents a serious problem to a conservator responsible for designing a packing case. As can be seen from figure 1, on page 5, the thickness of a given type of foam cushioning can be chosen only if the degree of protection required is known. For the measured fragility of the object, the likely height of a drop and the weight of the object per unit area will determine the necessary thickness of cushioning.

* The force of gravity or 'g' force is used as the standard unit of force.

However, paintings have been loaned nationally and internationally for many years. In spite of the problem outlined, packing cases have had to be provided and so it is worth assessing the properties of the cases that have been used.

At the Tate Gallery our packing case specification has developed over ten years, initially from the traditional concept of a rigid wooden case with foam cushioning, to its present form. In recent years, the design has not changed significantly so that a standard format is generally followed.

No obvious damages have occurred in transit using this specification except from incorrect repacking. The problem of monitoring the more subtle deterioration caused by loaning pictures is recognised. An example of this difficulty was on a loan to Russia when several reportedly crack-free paintings by Turner developed a crack system during the loan period. These paintings had recently been lined and the cracking may have been as a result of the subsequent re-stretching. Generally, though, the packing cases currently fabricated have performed well. So several years' experience have been gained using a set amount of cushioning material with little noticeable damage having occurred. It is therefore worthwhile to measure the fragility for which we are providing successful protection. To do this it is necessary to consider the height of the drops likely to occur in transit and measure the force acting on a packed frame under such circumstances. Such an assessment formed part of a series of tests undertaken to evaluate a Tate packing case. Details of the tests are reported later, see pages 3 & 4. For the results to be meaningful to those not familiar with the subject it is worth considering the mechanisms of shock and vibration on an object and the functioning of cushioning materials in reducing their adverse effects.

Shock, vibration and cushioning:

Let us consider the forces occurring when a case is dropped: as it falls it is accelerating under gravity. On impact the outer wooden casing will decelerate very suddenly. A large force will act on the casing for a short period of time. Foam cushioning causes the packed frame and painting to decelerate over a longer period. It does this by being compressed. Due to this extended deceleration time the force acting on the painting is greatly reduced, though it is of longer duration. As deceleration occurs, the foam will become increasingly compressed until the painting is momentarily at rest. The foam then starts to decompress causing the painting to accelerate in the opposite direction. This property is known as 'elasticity'. However, some of the energy passing between the frame and the foam will be dissipated and this property is called 'damping'. Without damping the painting would bounce back with equal energy.

If the foam becomes completely compressed before the painting has stopped decelerating, subsequently a large force will act on the painting due to the sudden deceleration. In this circumstance energy may be absorbed in causing structural damage to the painting.

Severe impact shocks are not inevitable. An accident involving the dropping of a case should be a rare event indeed provided there are sufficient numbers of competent handling-staff and well organised handling areas. But vibration during transit is unavoidable as the sources of vibration are the various modes of

transportation.

The common feature of vibration is an imposed force which repeats regularly with time. A variety of frequencies from one cycle per second to many hundreds of cycles per second may occur in transit. In most circumstances the force exerted is small compared with the force caused by shock on impact. Under certain circumstances, though, dangerous amplification of the vibration force may develop in the foam cushioning and the painting. This happens if the cushioning and/or the painting are caused to 'resonate' by an externally applied vibration.

A painting has a natural frequency of vibration as do all materials. The property is most obviously displayed by a drum skin. If a drum is repeatedly struck it will make the same note each time. Likewise a painting, if it is caused to, will vibrate at a characteristic frequency. This natural frequency will depend on the painting's tension, dimensions, elasticity and weight.

When two materials are in contact and one is being caused to vibrate, this force will be transmitted to the second material. If the frequency of the forcing vibration matches the natural frequency of the second material, the amplitude of the induced vibration will increase dramatically. This is because the small quantities of energy in the forcing vibration are being added together in the second material.

The same phenomenon occurs when a child on a swing is pushed from rest. Each successive push expends little energy but if applied with the correct regularity, i.e. at the correct frequency, the swing rapidly gains a high momentum.

An amplification of a forcing vibration in this way is called 'resonance'.

The degree of amplification will be limited in various ways. With a painting on canvas, for example, energy will be expended during each vibration in stretching and relaxing the canvas, resulting in stresses especially at the front turnover edges. Also the paint film will be flexed, first one way and then the other. Most of the energy will be dissipated by being converted to heat. In this way the attachment of the canvas to a rigid stretcher and the rigidity of the paint film apply a restraint against vibration. Unfortunately the consequence of the energies being absorbed due to this restraint may be the weakening of the structure of the painting (if the force of vibration at resonance is of sufficient magnitude).

'Transmissibility' is the term used to relate the energies of the applied ('forcing') and induced vibrations. The transmissibility is the ratio between the force of acceleration of the induced vibration divided by the force of acceleration of the input vibration. When the ratio is greater than one some resonance is occurring.

The transmissibility for a packing case can be used to indicate the maximum force of vibration likely to be experienced by a contained painting during transit. Table 2 gives maximum acceleration due to vibration for several modes of transport. The range of frequencies are listed, at which the maximum forces occurred. For example, if a packing case were found to have a maximum transmissibility of eight at 15 hertz, (as measured at the picture frame), a painting travelling in the packing case on a conventionally sprung lorry would experience a maximum force of vibration at the picture frame, of 1.7g x 8, or 13.6g. Such a figure cannot be directly related to a measured fragility for the frame. This is because vibrations in transit are caused by forces which recur regularly and rapidly over a period of time. Unlike the single large shock experienced during impact, the packaged item will suffer a series of shocks. These may well have a cumulative effect, thereby lowering the threshold at which damage occurs. Should the maximum vibration force be greater than the threshold for damage, then the case clearly provides insufficient protection. Commercially the measured transmissibility is used in a straightforward way. A figure of ten is taken as likely to cause damage to the packed item.

In our tests it was not possible to measure the force of vibration that the primed canvas was experiencing. This was due to the appreciable weight of the mounting for the accelerometer which would have completely distorted readings from the comparatively light canvas. Owing to the danger of the natural frequency of the painting exaggerating any transmitted vibration, it is wise to err on the side of caution when interpreting the transmissibility found by measuring the force of the induced vibration of the frame.

The Tate Packing case specification

Construction The outer wooden casing is fabricated from 12mm (½") thick plywood panels. The six faces are joined and reinforced where necessary with 75mm x 25mm (3" x 1") wood battens. All the battens are attached to the outside of the case with screws and glue. Two additional cross battens are attached to each of the four case edges to locate the case lid but those on the bottom (base) edge are in the form of 75mm (3") thick wooden blocks. Usually one of the large side faces is removable and serves as a lid. The lid is attached with captive bolts, approximately one every 380mm (15") of case edge. The case exterior is covered with three coats of paint.

Packing materials The inside of the case is lined with a continuous sheet of 1,000 gauge polyethylene. This serves as a moisture barrier. The polyethylene is held in position by the packing materials and is folded to make overlapping flaps on the face adjacent to the lid.

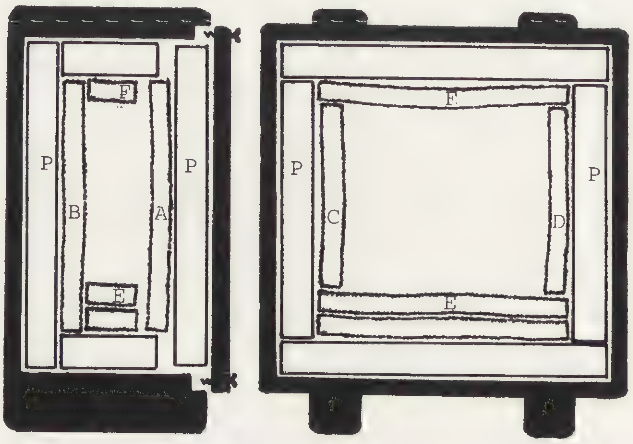


Diagram 1

Six panels of 100mm (4") thick insulated expanded polystyrene (EPS) serve as insulation and are placed next to the polyethylene sheet as can be seen in diagram 1 marked as 'P'.

Finally there is a cushioning interior comprised of seven pieces of 80-90 kg/m³ (6-8lb) density polyether chipfoam of 38mm (1½") thickness. Two thicknesses of cushioning are placed beneath the travelling edge of the painting as can be seen in diagram 1.

The test case: The case chosen for the series of tests had been fabricated according to the specification outlined above. The exterior dimensions of the case were 1,320mm (52") high, 1,385mm (54½") wide and 470mm (18½") deep.

A discarded frame that fitted (quite tightly) into this packing case was found. The frame measured 850mm (33½") high by 975mm (38 3/8") wide by 120mm (4 3/4") deep and was of a traditional gesso moulded and gilded type.

A stretched linen canvas was fitted into the frame. This had been primed with several coats of acrylic bound (Primal AC 73) chalk gesso. A hardboard backboard was attached to the back of the frame. The gross weight of the frame was 14.8 kg (32.5lbs). By measuring the area of contact between the frame and the foam cushions, the following static stress values were calculated.

Cushion A (as in diagram 1)	0.002	
" B	0.027	
" C or D	0.014	
" E or F	0.012	in kg/cm²

The gross weight of the packed case was 98kg.

Test procedure

Discussions took place between the authors and Sarah Staniforth of the National Gallery who was undertaking a similar study. Details of the vibration and shock tests were agreed to allow a comparison to be made between the results. The tests were carried out independently to ensure objectivity. (Unfortunately practicalities and inspirations on the day of testing resulted in some minor procedural changes. Even so, much of the value of the tests lies in the comparisons now possible.)

Vibration tests

The purpose of the vibration tests was to measure the maximum transmissibility of the case and to determine at which frequency this occurred.

Test Programme

The case was to be subjected to sinusoidal vibration in the range of three to one hundred to three hertz, (cycles/sec) sweeping at a logarithmic rate of one octave per minute with a constant acceleration input. Transmissibility was to be measured with two different acceleration inputs and with the case standing upright on its base and then repeated with the case standing upright on a narrow side. The forcing vibration was to be applied in the vertical axis.

Drop tests

The following drop tests were thought to be appropriate.

1. A six inch drop to simulate a fall from handling equipment such as a two wheeled trolley.
2. An eighteen inch drop to simulate a fall from a fork lift truck.
3. A thirty six inch drop to simulate a fall from a lorry's tail lift platform.

In reality the orientation of the packing case on impact would be unpredictable, but for the results to be comparable the drops were made onto the flat base of the case.

Three more tests were devised.

4. One end only of the upright case to be lifted six inches and dropped.
5. Test four to be repeated, but with the end dropped from eighteen inches.

These two tests were to simulate the drop which may occur when the packing case is pivotted on one end to remove a two wheeled trolley from beneath it.

6. A topple test by balancing the packing case on a long base edge and then releasing the packing case so that it impacts against one of its large faces.

This was to simulate an accident which would occur if the case were accidently knocked over.

Test Venue: The vibration and shock tests were carried out by Pira, the research association for the paper and board, printing and packaging industries, Leatherhead, Surrey, England on 23 November 1983.

Apparatus

Servotest Electrohydraulic vibration tester
DJ Birchail acceleration transducers
Fylde Signal conditioning equipment
Pira RMS converter
Watanable XY chart recorder
Webbing Straps, Quick Release Mechanism,Hoist

Accelerometer attachment: Triaxial piezoelectric accelerometers were attached half way along the base edges of the packing case and the frame, see photo 1

Photo 1 Attaching the accelerometers

Photo 2 Tate packing case installed on the vibration tester

Test Results

Vibration

Packing Case Orientation	Input acceleration	Resonant Frequency	Maximum Transmissibility (picture frame)
Upright on base	0.4g	21.5 Hz	4.9
"	0.7g	20.5 Hz	4.2
Upright on narrow side	0.4g	17.5 Hz	4.4
"	0.7g	17.0 Hz	3.8

Table 1

From table 1 it can be seen that with a constant vibration force of 0.4g and with the case standing on its base, a maximum transmissibility of 4.9 occurred at 21.5 hertz. However when the vibration force was 0.7g and with the case similarly oriented, the transmissibility reduced to 4.2. The resonant frequency also changed to 20.5 hertz. This small shift of resonant frequency with an increased input is commonly observed to occur (4) though difficult to explain.

Mode of Transport	Frequency Range Monitored	Maximum Force Measured	Frequency Range of Maximum Force
Conventionally sprung lorry	Up to 500 Hz	1.7g	10-20 Hz
Boeing 707	Up to 2,000Hz	0.6g	50-400Hz
Railroad	Up to 600 Hz	1.5g	30-300Hz

Table 2 Information courtesy of Pira

Discussion

A comparison of the data in tables 1 and 2 shows that the resonant frequency found to occur in our test is very close to the frequency range of the maximum vibration force caused by a conventionally sprung lorry. This gives cause for concern. As previously explained, there is a likelihood that the force of the vibration will be amplified further by the stretched canvas.

Using the data in the tables, a maximum force of vibration during transit by lorry can be calculated. We will assume that the maximum transmissibility would remain at 4.9 and that a maximum input force of 1.7g would occur. So, in this circumstance, a vibration force of 8.3g would be experienced by the frame of the painting. It is impossible to interpret usefully this figure for reasons previously discussed. However the frame and primed canvas were examined following the completion of the programme of vibration tests and no damages were observed to have occurred.

The maximum force of vibration experienced by the frame during our tests would have been 0.7g x 4.2 (the maximum transmissibility at 21.5 hertz) or 2.9g.

Shock

Note: The drop tests were carried out in the same order as the results are listed.

Impact against:	Height of the drop	Maximum force of Impact (Peak g) measured at the: Picture Frame	Base of the case
Flat base	6"	18.4g	25.9g
(Pivot on end) dropped onto base	6"	7.6g	21.3g
(Pivot on end) dropped onto base	18"	11.4g	36.8g
Flat base	18"	27.8g	83.0g
Flat base	36"	49.0g	130.4g
Topple onto large face		25.9g	(26.3g*) 32.1g

Table 3

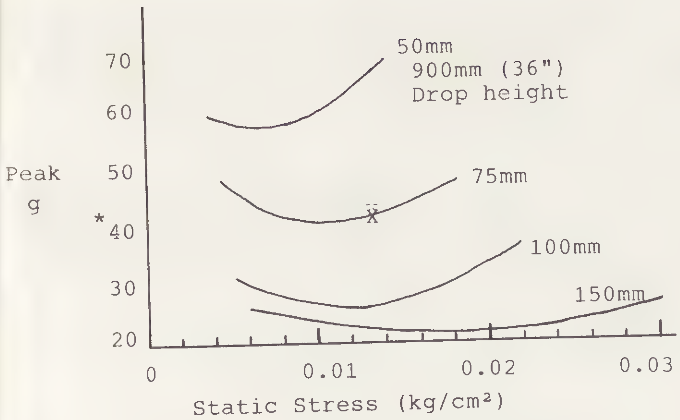
Photo 3 The topple test

Discussion

Following the sequence of drops, the packing case was opened and the contents examined. The frame had suffered noticeable damage in the form of a widening of the gap in the corner mitre at the top left corner (as viewed from the front). Also several very small fragments of gesso and gold had broken off. Therefore, it can be concluded that the maximum force experienced by the frame, i.e. 49.0g was greater than its structure could withstand and that damage resulted. This indicates the degree of the frame's fragility. The primed canvas suffered no apparent damage.

It is worth comparing the maximum deceleration force measured with published peak g/static stress curves.

The graph in figure 1 (3) shows such curves for the foam used in the Tate case. The static stress, e.g. weight per unit area, of the frame on the cushion in the test packing case was calculated for each cushion as noted previously. Beneath the base edge of the frame the static stress on the cushion was 0.0126 kg/cm². At this loading a predicted maximum deceleration of 42g should have occurred on impact following a 36 inch drop.



* Predicted peak g (base cushion) in the 36 inch drop test

Figure 1 Deceleration/static stress curves for chipfoam of density 80kg/m³ (6lb/ft³)

It is encouraging that from the graph in figure 1 it appears that the base edge cushion was at its most efficient in our test, i.e. the minimum point of the curve.

By comparison the static stress on the cushion adjacent to the backboard of the frame can be seen to be well below the static stress for maximum efficiency. The static stress for this cushion was calculated to be 0.002 kg/m². The effect of this can be seen in the tests by comparing the impact forces measured in the topple test. (The impact in the topple test was against the large side of the packing case adjacent to the back of the picture frame.) On the picture frame the force experienced was 25.9g compared with 26.3g in the same plane for the base of the container. It must be remembered that the accelerometers were located on the base edges of the frame and case close to the pivoting point of the toppling packing case. A much higher reading would have been recorded had they been placed at the top of the case. Similarly, the accelerometer on the packing case was slightly closer to the pivoting point than the accelerometer on the frame. (This will have reduced the force acting on the packing case accelerometer relative to the force acting on the frame accelerometer.) Despite these reservations a useful indication is provided as to the excessive rigidity of the chipfoam cushion against the backboard.

Environmental Tests

The purpose of the first test was to monitor how the cases behaved under randomly varying external temperatures and humidities.

First test procedure: Two cases with a similar package capacity were continuously monitored for a period of three weeks in a sheltered area open to the outside environment. The test period was from 22 July to 12 August 1983. Case 'A' was insulated with a 4 inch thick expanded polystyrene (EPS) layer whereas case 'B' had only a 2 inch EPS layer. To hold the chipfoam elements in position an EPS cross was placed in the space normally occupied by the work of art in each case. This reduced the inner air volume (as would a framed painting) but did not provide a buffering effect against fluctuating humidity. This arrangement allowed the effect of the packaging alone to be monitored.

Monitoring equipment

Mains operated GPE Electronic Thermometer, manufactured by Zeatron with a tested accuracy of ±1% of span.

PJD Digital Hygrometer (Phillips) with a tested accuracy of ±1%RH.

The two cases had been stored in the same stable conditions for several months and their lids were removed 48 hours before the test started. Initially the conditions within the closed cases were measured to be: Case A - 52%RH at 24°C; Case B - 53%RH at 24°.

Results of the first test: The cyclical nature of the imposed environment allowed general trends to be illustrated. Most interestingly, the humidity was found to rise as the temperature rose. Enclosed air would be expected to show the opposite response. The foam must, therefore, be providing a moisture reservoir which dominates the RH response of the air in the packing case.

Second test procedure: Having obtained general information on the behaviour of the case, a second test was devised to isolate a constant factor which would enable a comparison to be made with other cases. The temperature half-time (t0.5) was chosen as a measure of the insulating quality of the case. For an instantaneous 'stepped' change in external temperature the rate of change of interal temperature will be proportional to the temperature difference between inside and outside the packing case. This relationship ensures a constant t0.5. The relative humidity was also monitored to observe how it varied with temperature.

Environmental test results 9 February 1984

The packing case had been stored outside for a week prior to the test. The packing case was brought into the Tate Gallery at 9 o'clock 9 February 1984

Readings

Time	Temperature °C At the Frame	Temperature °C Externally	%RH *Inside Polyethylene	%RH Outside Polyethylene
8.30	5.0	3.5	43.6	43.1
9.30	5.0	18.5	43.5	43.1
10.00	5.0	19.5	43.6	43.7
10.40	5.0	20.3	43.7	45.2
11.10	5.0+	20.5	43.8	46.1
11.35	6.5	20.3	43.8	47.1
12.00	6.8	20.6	43.9	47.7
12.30	7.0	21.3	44.0	48.5
13.05	7.5	20.5	44.2	49.2
13.35	8.0	20.6	44.4	49.6
14.10	8.5	20.6	44.6	50.0
14.30	9.0	20.6	44.7	50.2
15.00	10.0-	21.1	45.0	50.5
15.30	10.0-	20.6	45.2	50.6
16.00	10.0	21.4	45.4	50.8
16.30	10.0+	21.3	45.7	50.9
17.12	11.0	21.4	45.9	51.0
19.25	12.0+	21.6	47.0	51.3

* For this test the frame was first wrapped in polyethylene. The conditions inside and outside the polyethylene wrapping were monitored.

Table 4

Temperature half-time

The temperature half-time is calculated from the rate equation (5).

$$\frac{-dT}{dt} = k(T - T_1)$$

where T = temperature at time t
K = rate constant
T_1 = room temp.
T_o = inital temp.

hence $\log_e \frac{(T - T_1)}{(T_o - T_1)} = -kt$

therefore $\log_e (T-T_1) = -kt + \log_e(T_o-T_1)$

plotting $\log_e (T-T_1)$ against time gives a straight line graph of slope -k and intercept $\log_e (T_o-T_1)$.

At half-time $t_{\frac{1}{2}} = \frac{1}{k} \log_e \frac{1}{2} = \frac{0.693}{k}$

From the results the slope for the Tate packing case is calculated to be -0.0667

therefore $t_{\frac{1}{2}} = \frac{0.693}{0.0667}$ = 10.4 hours.

Discussion

The Tate packing case was found to provide reasonably good protection against rapid changes in external temperature. However, it is clear that the case cannot be expected to protect the works from extremes of temperature if left in hot or cold conditions for more than a few hours (T0.5 = 10 hours).

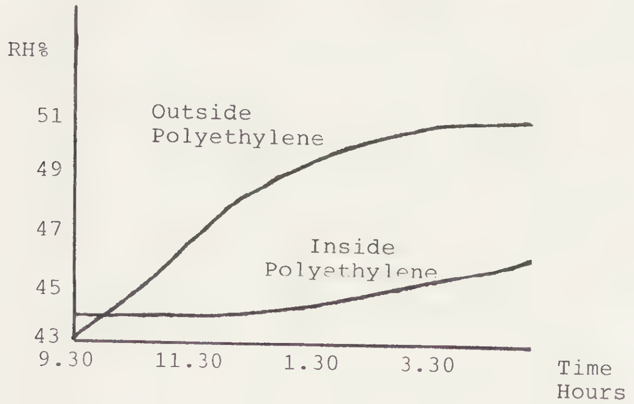


Figure 2 Changes in RH within the packing case with rising temperature.

The slow rate of change in RH experienced by a polyethylene wrapped painting and frame was encouraging. During the course of the tests the RH remained within acceptable limits (40-60%) (1).

Conclusions

The programme of environmental tests of the Tate packing case is continuing. Before firm conclusions can be made the moisture content of the frame and painting support must be considered. As the temperature varies so will the RH necessary to maintain the equilibrium moisture content of the painting support (6).

Nevertheless the small changes in RH and the slow response rate are encouraging. Wrapping the frame in polyethylene has been justified. Although the temperature half-time is only 10 hours, reducing the quantity of insulating material could be considered in less extreme climates.

The shock tests highlighted the need for a less resilient cushion (or less contact with the cushion) against the painting's backboard. In the vibration tests the maximum transmissibility measured at 21.5 hertz needs to be related to the, as yet, undetermined range of natural frequency exhibited by paintings.

The correlation between the resonant frequency of the Tate packing case and the forces experienced on a traditionally sprung lorry must be assessed. Changes to the foam cushioning or the careful selection of the lorry may be necessary.

Despite the problems of interpretation it is hoped that the results provide a useful comparison with other results presented at the conference and will be a step towards the establishment of standards.

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Acknowledgement

The authors would like to express their gratitude to Tina Sitwell, private consultant. The Tate packing case was tested together with a packing case being developed by Tina Sitwell to whom a grant was awarded by the Small Firms Technical Enquiry Service. This grant made the testing possible.

We would also like to thank Peter Booth, Conservator, Tate Gallery, who is largely responsible for the current Tate Gallery case specification.

THE TESTING OF PACKING CASES FOR THE TRANSPORT OF PAINTINGS

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Summary

The two styles of packing cases used by the National Gallery, London, for the transport of paintings are described. The cases have undergone environmental, waterspray, drop, vibration and impact tests to assess their performance. The tests are described and the results are discussed with a view to improving the performance of the cases.

1 Introduction

In papers that have been written about the principles of the packing of paintings, authors agree that the function of a packing case is to guard its contents against impact, shock and vibration, to provide a reasonably water-tight seal and to buffer the internal environment of the case against external changes of temperature and relative humidity (1,2,3). With these factors in mind the new packing cases that are used by the National Gallery were tested to see how adequately they fulfil their functions. The drop tests and vibration tests were designed in collaboration with the Tate Gallery so that the results would be comparable and would provide a basis from which a specification could be suggested.

2 Description of Packing Cases

The packing cases, which have been used regularly by the Gallery since 1982, have been designed to be used for a number of journeys (4). The inside furnishing of the cases can be adjusted so that each case can fit a number of paintings of different sizes. The frame sizes of a selection of paintings in the collection were surveyed to select a range of standard sizes for the cases (5). Four standard sizes of packing case were chosen to fit the frame sizes given in Table 1.

	STANDARD FRAME SIZES (MM)	EXT DIM OF CASES (MM)	WEIGHTS (KGS) PC	DFA
1	680 x 555 x 125	810 x 685 x 230	18	24
2	940 x 740 x 125	1070 x 870 x 230	22	30
3	1200 x 925 x 125	1330 x 1055 x 230	26	36
4	1460 x 1110 x 125	1725 x 1385 x 315	82	106

TABLE 1 STANDARD SIZES OF FRAMES AND CASES AND WEIGHTS OF CASES MADE FROM PHENOLIC-COATED (PC) AND DOUBLE-FACED-ALUMINIUM (DFA) PLYWOOD

For pictures that are larger than the standard sizes cases are tailor-made. Occasionally it has been possible to re-use these if large pictures of similar sizes have been requested for loan. The cases are made in two styles, the three smaller standard sizes in Style 1 and the largest standard size and the tailor-made large cases in Style 2.

2.1 Style 1

Panels of 9mm phenolic-coated or double-faced-aluminium plywood are joined with a polyurethane elastomer moulding which gives the containers a certain flexibility. The same elastomer is moulded to provide an interlocking seal between the base and lid. The lid is hinged to the base with an aluminium piano hinge and on each side there are webbing restrainers connecting the lid to the base to prevent the lid from opening flat. The case is closed with quick-release fasteners which either incorporate a lock or can be secured with padlocks. Spring-loaded handles are fitted to the case.

The case is lined with 25mm of the closed-cell polyethylene foam 'Plastazote' (6). The painting sits on cushions of the same foam. These are cut to size for each painting. Their minimum size is 25mm underneath the painting and 25mm on each side. The frame is directly in contact with the lining of the lid of the case. The number and positioning of these cushions depends on the size of the frame and its ornamentation.

The thickness of the foam lining, the foam cushions and the plywood makes the width and length of the cases at least 120mm and the depth 95mm greater than the frame sizes. The external dimensions of the standard size cases are given in Table 1. Their weights are also given. The cases are finished with elastomer feet on the base and soft-wood skids with elastomer pads on the standing edge either side of the piano hinge to protect it when the case is standing upright. Internationally-recognised symbols for 'right-way-up', 'delicate contents' and 'protect from rain' are stuck on the outside.

2.2 Style 2

To increase rigidity soft-wood battens are attached to the exterior of the larger cases. Blocks are placed on the base of the case so that it can be lifted by a fork-lift truck. The lid can be lifted off the base and a seal is made using a self-adhesive PVC foam tape attached to the lid round the join. The same fastening system and spring-loaded handles are used as for the Style 1 cases. The cases are lined with 50mm of 'Plastazote' foam and the painting sits on an appropriate number of cushions of the foam of minimum thickness 25 mm. Figure 1 shows a photograph of the styles of cases.

FIGURE 1 STYLE 1 CASE CONTAINING PAINTING WITH STYLE 1 CASE ON RIGHT AND STYLE 2 CASE BEHIND

3 Tests on the Cases

Two cases were tested (7): a Style 1 case of the second standard size and a Style 2 case of the largest standard size. For all of the tests (except the waterspray) the cases contained framed canvases. These paintings were prepared in the same way that paintings usually leave the Gallery when loaned. They were not glazed. A backing board of 5mm hardboard was attached to the back of the frame with screws. The paintings were not wrapped and were placed face-up in the case so that the back of the frame rested on the foam cushions.

3.1 Environmental Tests

Both cases were fitted with platinum resistance thermometers and humidity sensors. The leads from these devices were taken out through a small hole cut in the cases (and sealed around the leads to prevent air leakage) and connected to a chart recorder outside the test chamber. Conditions inside the cases could be observed and recorded during the tests. Temperature and humidity recorders with solid-state memories (8) were put in each case as a check. The cases with the frames and canvases were left open for one week in the Test House to allow them to equilibrate with environmental conditions.

3.1.1 Cold Test

The cases were placed in the cold chamber at Test House conditions (14.5^{o}C and 40%RH). Liquid nitrogen was used to reduce the chamber temperature rapidly to -10^{o}C and to keep it there until the internal conditions in the cases had stabilised. After approximately 18 hours the cases were returned to Test House conditions by switching off the liquid nitrogen and opening the chamber doors. The changes in temperature and relative humidity inside the cases are shown in Figure 2A. The unopened cases were left for three days to allow them to re-equilibrate to Test House temperatures.

3.1.2 Hot-Humid Test

The cases were taken from Test House conditions (16^{o}C and 44%RH) and placed in a chamber operating at a temperature of 40^{o}C and 95-100%RH. The cases were left for 18 hours and then returned to Test House conditions. The changes in temperature and relative humidity inside the cases are shown in Figure 2B.

FIGURE 2A   RESULTS OF COLD TEST

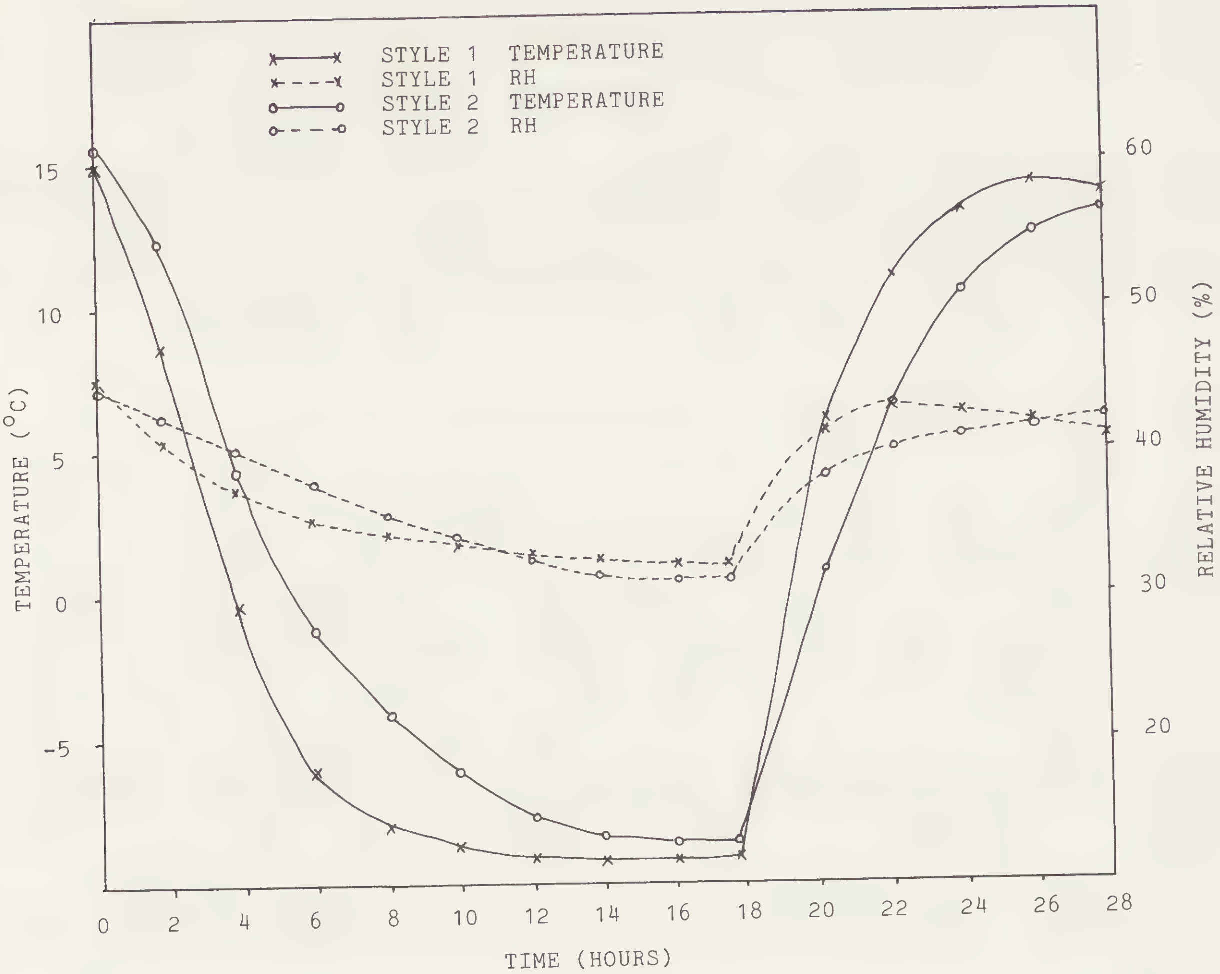
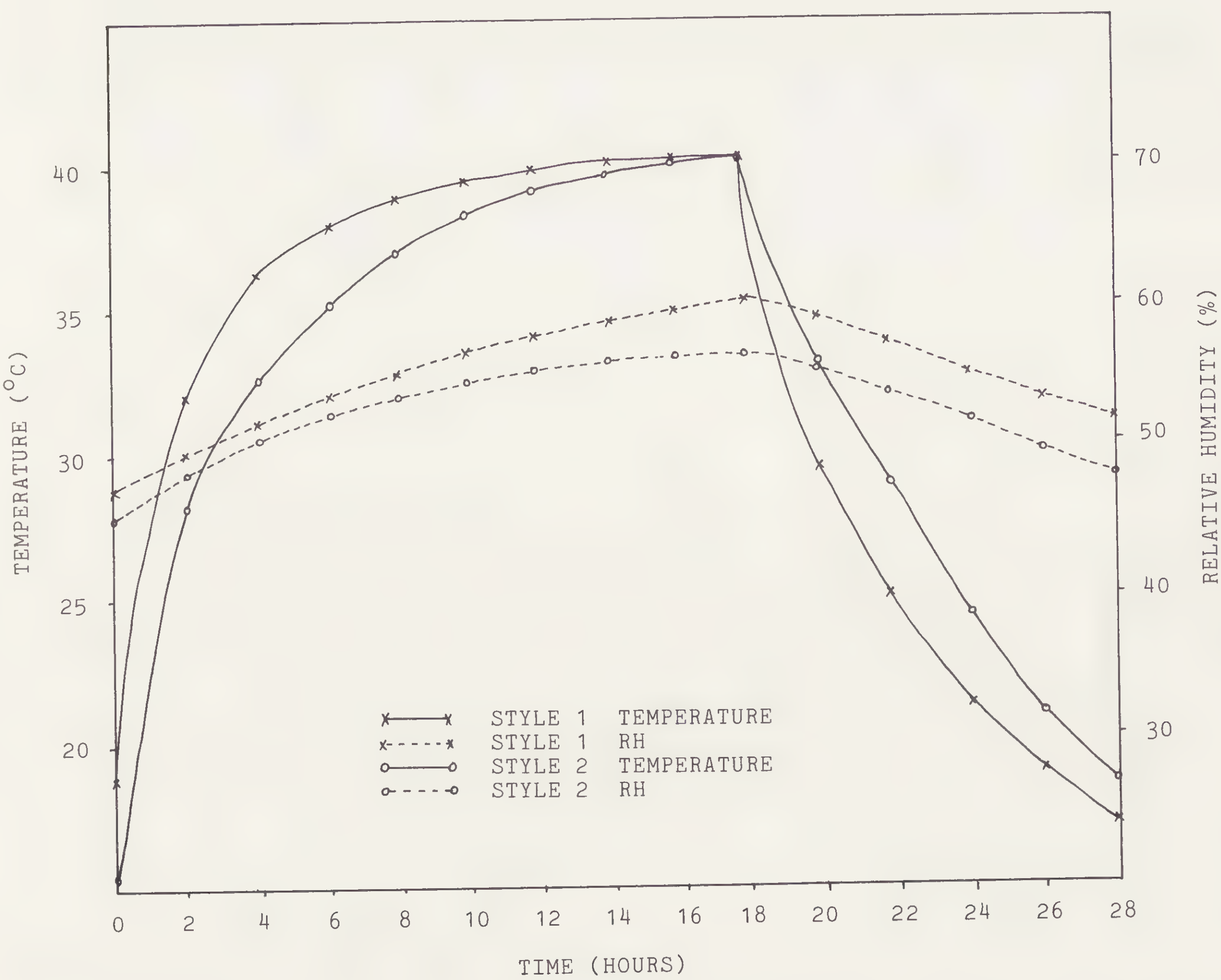


FIGURE 2B   RESULTS OF HOT-HUMID TEST



3.1.3 Results and Interpretation

The temperature in the Style 1 case took approximately 8.5 hours to fall from 15°C to -10°C and about the same time to rise from 15°C to 40°C. The Style 2 case took approximately 13 hours to change over the same intervals. The total relative humidity changes, for both cases, for both the temperature changes of 25°C was 13%RH ± 1%.

The relative humidity rises as temperature rises and falls as temperature falls. This result is predicted in an article by Garry Thomson (9) in which he concludes that for a volume of air in a case which contains an excess (more than 1 kg/m^3) of wood the RH will change in the same direction as temperature by about 0.35%RH for each °C change in temperature. In fact, in this test the RH has changed by approximately 0.5%RH for each °C change in temperature. Almost the entire weight of the frame and backboard is made up of wood and the volume of air trapped within the case in small.

	Volume of air (m^3)	Weight of frame and canvas (kg)
Style 1 case	.12	11
Style 2 case	.27	23

Each case contains almost the equivalent of 100 kg of wood per cubic metre of air. The RH of the air within the case is being controlled by the painting and the materials associated with it.

Silica gel could be used in the cases to limit the RH changes but it would be necessary to use a substantial amount relative to the weight of the painting (10). The results indicate that condensation is not likely to be a problem even if the temperature in the case falls below the dew-point but it might occur if the case were opened when the contents were very cold and moist air were to condense on these cold surfaces. To prevent this happening cases are not opened until at least 24 hours of equilibration in Gallery conditions.

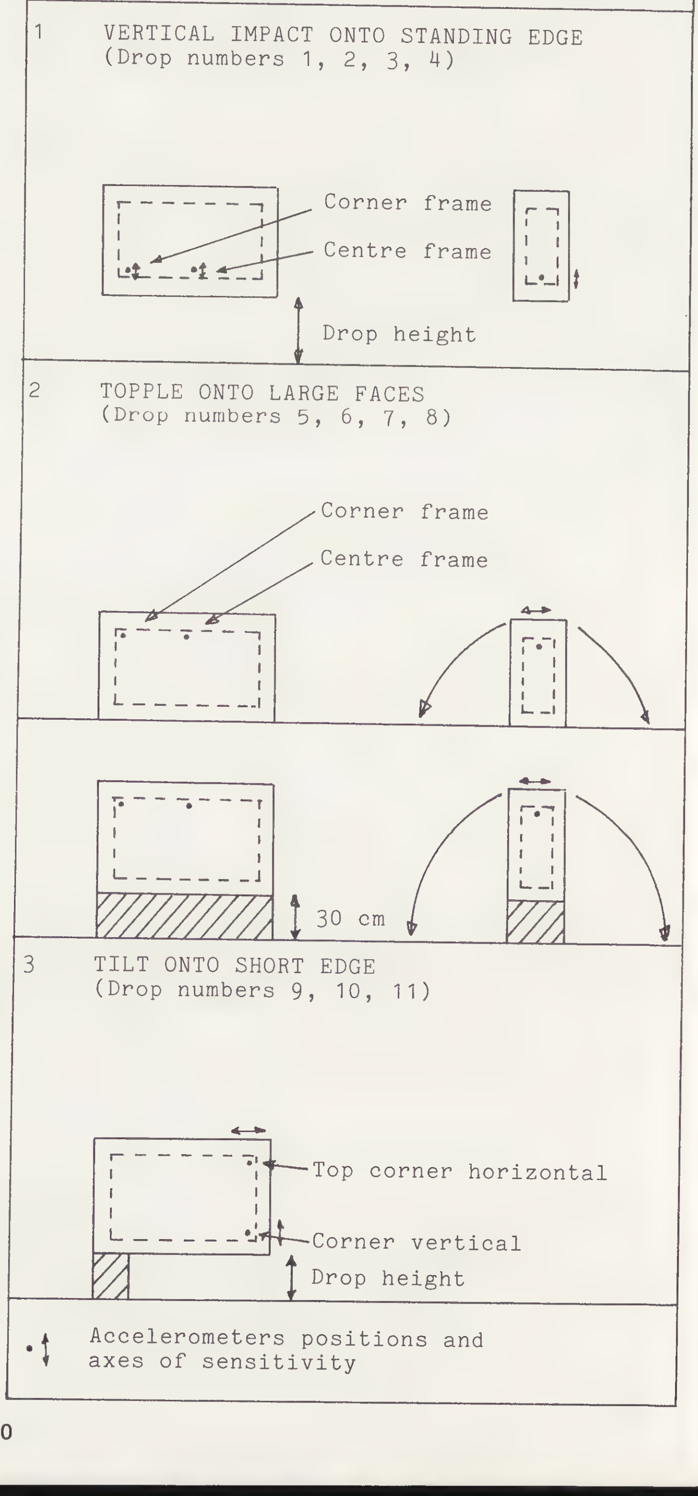
3.2 Waterspray Test

Both cases were stood on their standing-edges, the orientation in which they are transported, and were sprayed with droplets of water which were equivalent to rain falling at 200mm per hour. The droplets were falling at approximately 45° to the vertical. This test represents the heaviest rainfall which may last for more than a very brief period, possibly up to one hour. Heavy rain falls at about 45° to the vertical in winds of 25 to 30 km/hour. The test was carried out for 15 minutes. After spraying the cases were left for 2 hours before examination. The water sat on the tops of the cases and collected in the interlocking seal on the Style 1 case. Before the cases were opened this water was wiped away so that it would not be drawn into the cases when they were opened. The Style 2 case was completely dry inside but a small amount of water (too little to collect and measure) had entered the Style 1 case.

3.3 Drop Tests

Accelerometers were fitted onto the two frames to monitor impacts in the three principal axes of the cases. These accelerometers record 'G', the acceleration (deceleration) that the dropped object receives at impact, expressed as a multiple of the acceleration of the earth's gravity. Each frame was fitted with five accelerometers and their positions and axes of sensitivity are illustrated in Figure 3 which also shows the configurations of the three types of drops. The cases were dropped onto a 6mm. mild-steel plate bolted down onto a concrete block 0.46m thick.

FIGURE 3 DROP TEST CONFIGURATIONS AND ACCELEROMETER POSITIONS



3.3.1 Vertical Drops

These tests were designed to measure the deceleration at two points on the frame when the case was dropped from various heights onto its standing edge. One accelerometer was located at the centre of the frame member at the bottom of the case and the other at one corner of the frame at the bottom of the case. The Style 1 case was dropped from 15, 30, 60 and 90 cms and the Style 2 from 15, 30, 45 and 60 cms. Although this type of drop is less likely to occur in practice than the following two, it does demonstrate how adequately the foam is cushioning the painting in the vertical orientation.

3.3.2 Topple Drops

These tests were designed to simulate a case unbalancing from its standing edge and falling onto its base and lid. Each test was repeated with the case unbalancing while standing on a block 30 cms high. This is the type of drop that a case might experience if it were allowed to fall when being carried on a fork-lift truck. The decelerations were measured by an accelerometer mounted in the centre of the frame member at the top of the painting and by a second accelerometer mounted at one of the top corners. In effect this represented a vertical drop from the height of the container and the height of the container plus 30 cms. It tests the cushioning power of the foam in the lid and base of the case.

3.3.3 Tilt Tests

Both cases, standing upright, were supported horizontally at one end and allowed to fall freely from heights of 15, 30 and 60 cms. This drop might occur if one end of the case were dropped whilst it was being carried. The decelerations were measured by one accelerometer mounted on the bottom corner of the frame at the end that was dropped and by a second that was mounted on the top corner of the frame to measure the horizontal values.

3.3.4 Results and Interpretation

The results of these tests are shown in Table 2. It is possible for cases to experience drops like these not only through careless handling but also if the case is 'shunted' or if it can bounce during transport in a vehicle.

In order to make sense of these results we need to be able to relate them to damage that occurs to the painting and its frame. During this series of drops the mitres of each frame opened slightly, small pieces of moulding broke off and two screws from the backboard of the larger painting came away during the topple test. There was no visible damage to either of the paintings. However deterioration as a result of these drops may become visible in the future after cracks have had time to develop. It should be noted that this damage has resulted after a number of drops, each of which would probably have been considered worrying if they had occurred while a real painting was travelling. The accelerometers were all located on the frames. The G values experienced by the canvases would have been less than those recorded on the frames as the frames absorb some of the energy of the impact.

A short digression into mechanical shock and package design may help in the understanding of these results.

TABLE 2 RESULTS OF DROP TESTS

			STYLE 1					STYLE 2				
DROP TYPE	DROP NUMBER	DROP FACE	DROP HEIGHT (CM)	PEAK DECELERATION (g_n)				DROP HEIGHT (CM)	PEAK DECELERATION (g_n)			
				CENTRE FRAME VERT	CORNER FRAME VERT	CORNER VERT	TOP CORNER HORIZ		CENTRE FRAME VERT	CORNER FRAME VERT	CORNER VERT	TOP CORNER HORIZ
VERTICAL IMPACT ONTO STANDING EDGE	1	-	15	18	27	-	-	15	28	32	-	-
	2	-	30	33	37	-	-	30	40	46	-	-
	3	-	60	48	55	-	-	45	50	55	-	-
	4	-	90	63	75	-	-	60	60	65	-	-
TOPPLE ONTO LARGE FACES	5	LID	-	90	90	-	-	-	130	130	-	-
	6	BASE	-	115	95	-	-	-	135	145	-	-
	7	LID	30	100	90	-	-	30	120	115	-	-
	8	BASE	30	95	110	-	-	30	100	95	-	-
TILT ONTO SHORT END	9	-	15	-	-	22	12	15	-	-	26	15
	10	-	30	-	-	32	20	30	-	-	37	20
	11	-	60	-	-	48	40	60	-	-	50	30

3.3.5 Mechanical Shock and Package Design

When a case is dropped it and its contents are accelerated towards the ground at 1 g_n (g_n is the acceleration due to the earth's gravity). On impact the kinetic energy contained in the case and its contents must be used up by doing work. Work is done when a force moves through a distance:

Work = Force x Distance

From which we get:

Work = Mass x Acceleration x Distance

On striking the ground there is a deceleration force which acts over a distance. This distance is the deflection of the ground, the interface of the case and the ground and the contents of the case. If there is no resilience in any of these, then there is no distance over which the deceleration can act, and in order to use up the kinetic energy the case and its contents must be subject to an infinitely high deceleration.

A shock protection system in a case is designed to limit the shock experienced by the contents to within acceptable limits. The shock protection system controllably reduces the velocity of the contents to zero and absorbs the energy of impact. In our packing cases the polyethylene foam acts as the shock protection system since the foam compresses on impact, thus allowing the painting to move within the container.

As a rule of thumb the following equation may be used in calculating the thickness of cushion to be used inside a case. This assumes that the cushion is performing at optimum static loading, that it is neither over- or under-compressed.

$$G_f = 2h / d$$

h is the drop height. The value chosen for this must be a realistic assessment of the maximum height from which a case is likely to be dropped. There are values for this available that are based on the weight of a container and its contents. d is the compressive deflection of the cushion on impact. The cushion thickness should be between one and a half times and twice this to ensure that on impact the frame cannot come into contact with the outer container.

Extremely fragile : Precision instruments	15 - 25 g_n
Very delicate : Electronic equipment	25 - 40 g_n
Delicate : Typewriters, cash registers	40 - 60 g_n
Moderately delicate : Television receivers	60 - 85 g_n
Moderately rugged : Refrigerators, washing machines	85 - 115 g_n
Rugged : Machinery	115 g_n up

TABLE 3 APPROXIMATE FRAGILITY FACTORS OF TYPICAL PACKAGED ARTICLES

G_f is the fragility factor and is expressed in multiples of g_n. It is defined as 80% of the acceleration at which damage occurs. Table 3 gives some approximate fragility factors of typical packaged articles. One of the problems facing us if we decide that it is desirable to package paintings to a specification that minimises mechanical shock is to define a fragility factor for paintings.

In selecting a cushioning material and calculating optimum static loading cushion performance data is required. This is usually available from manufacturers and suppliers of foams. The loading of the foam is the weight of the painting divided by the area which is in contact with the foam, it is expressed in units of kg/cm^2. The optimum loading can be determined from the cushion performance curves and at this loading the cushion performs at maximum efficiency.

Our packing cases have not been designed to give optimum cushion performance but comparison of the peak decelerations measured in the drop tests with the cushion performance curves for 'Plastazote' do indicate that the loading is of the right order of magnitude for vertical drops. The high decelerations recorded for the topple tests indicate that the loading on the foam in the lid and base is not optimum. Decelerations could be reduced by using thicker cushions of foam at the optimum static loading.

3.4 Vibration Tests

Each painting had four accelerometers mounted on the frame: in the corner and centre of a long frame member and in the corner and centre of a short frame member. These were mounted to record responses in the appropriate axis of vibration. The position and axes of the accelerometers and the attitude of the cases during the tests is shown in Figure 4. In addition a very light accelerometer was mounted in the centre of the two canvases to measure the cross-axis response (that is, any vibration occurring perpendicularly to the input vibration).

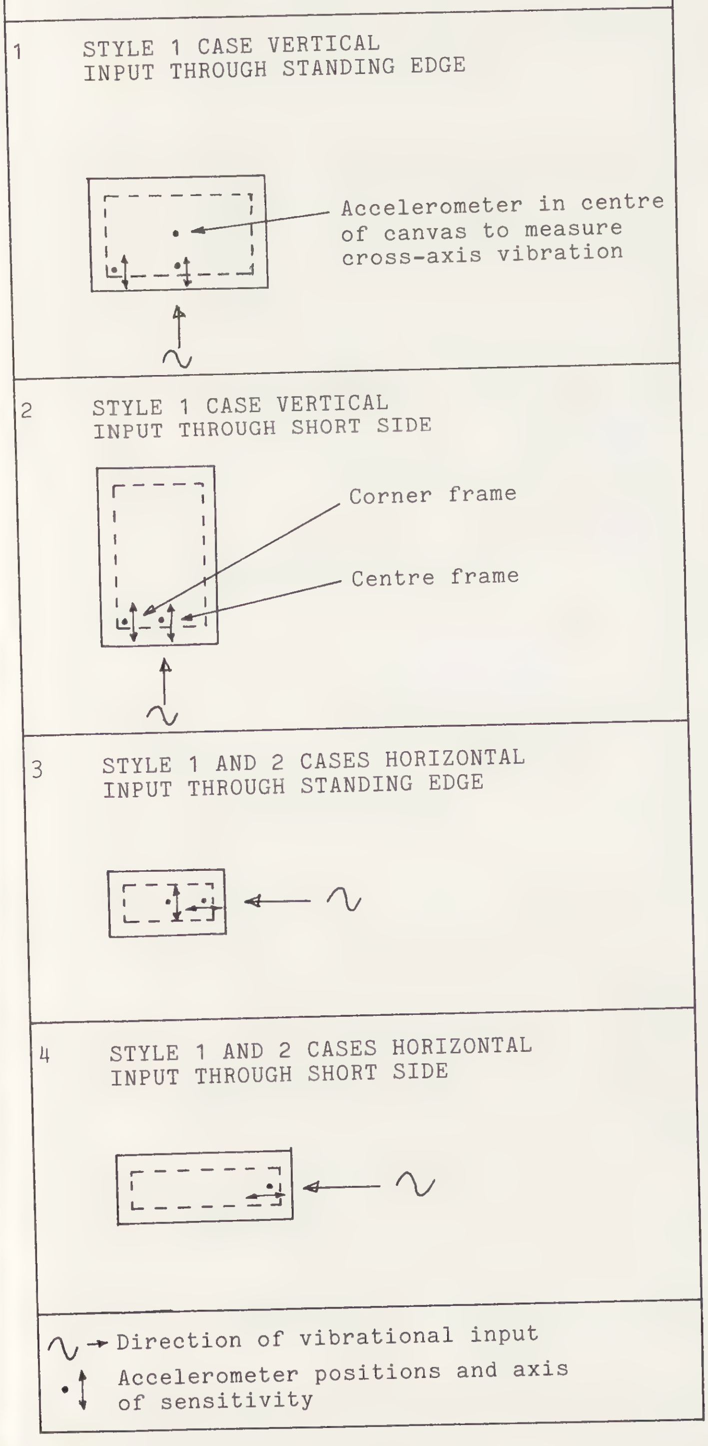
3.4.1 Resonance search

Vibrational resonance searches were performed with the cases in different orientations. The G values recorded by the accelerometers were compared to the input vibrations at each frequency. These response curves were recorded during the ascending frequency sweep as the cases were subjected to sinusoidal vibration. The rate of sweep was less than 1 octave per minute over the frequency range 5 Hz to 290 Hz and the magnitude of the vibrational input was:

5 Hz to 9 Hz $\pm$ 6mm
9 Hz to 290 Hz $\pm$ 2g_n

The Style 1 case was vibrated vertically when standing on its standing-edge and one short side and also horizontally lying on its base with the vibration input through the standing-edge and one short side. The Style 2 case was only subjected to the horizontal vibrations. The case was too large to be stood vertically on the vibration table. By comparison of the results for the horizontal vibrations of the Style 1 case with the vertical vibrations we felt that it was possible to extrapolate the results from the horizontal vibrations of the Style 2 case to how it would behave when standing vertically.

FIGURE 4 VIBRATION TEST CONFIGURATIONS AND ACCELEROMETER POSITIONS



3.4.2 Results

The response curves are presented as a logarithmic plot of G, the acceleration recorded by the accelerometers, against frequency. When a resonance occurs the recorded G is much greater than the input G and may be large enough to cause damage. The input G is also drawn on the response curves. Figure 5A shows the response curve recorded from the accelerometer mounted in the centre of the long frame member for vertical input vibration with the Style 1 case standing on its standing-edge. The principal resonance occurs at 48 Hz and magnifies the input by approximately 2.5. Table 4 gives the principal resonances and their magnification factors for the various orientations of vibrational input for the two cases.

Since the principal resonance of the Style 1 case is higher when vibrated vertically than when it is vibrated horizontally we may assume that the principal resonance of the Style 2 case will also be at higher frequency, perhaps in the range of 30 - 40 Hz, when it is standing vertically.

The shape of the response curves for the accelerometers mounted on the frames are all similar and show no dramatic resonances. This is not true of the response curves for the accelerometers mounted in the centre of the canvases. Figure 5B shows this for the small canvas when standing vertically. This shows a number of resonances of significant magnification. The principal resonance occurs at 50 Hz and has a magnification factor of 5.5. This is a displacement of just under 2.5 mm of the centre of the canvas where the accelerometer is located. The principal resonances and the magnification factors for the small and large canvases with the cases vibrated horizontally are given in Table 4. The displacement of the centre of the small canvas in this orientation is 2mm and of the large canvas is 1mm.

3.4.3 Discussion

The response curves from the accelerometers located on the frames show that resonances are not in the range of the most energetic vibrations in the various forms of transport. For road vehicles this range is from 2 - 20 and 50 - 70 Hz and for jet aircraft is 300 - 500 Hz. We should note that this method of testing for resonances by sweeping up the vibrational scale does not represent the random nature of vibrational input during transport. It will tend to enhance resonances by building up to them.

The results from the accelerometers placed on the canvases are more worrying. These measure cross-axis vibrations that occur perpendicularly to the plane of vibrational input. Much larger resonances might occur if the vibrational input was perpendicular to the plane of the canvas. It seems inevitable that a canvas will vibrate during transport and it is not easy to see a method of preventing this in the packing system without immobilising the canvas. At the moment, as with shock, we have no way of relating vibration to damage. These results suggest that this may be an area for further research.

FIGURE 5A RESPONSE CURVE FOR CENTRE FRAME ACCELEROMETER IN STYLE 1 CASE STANDING VERTICALLY WITH VIBRATIONAL INPUT THROUGH STANDING EDGE

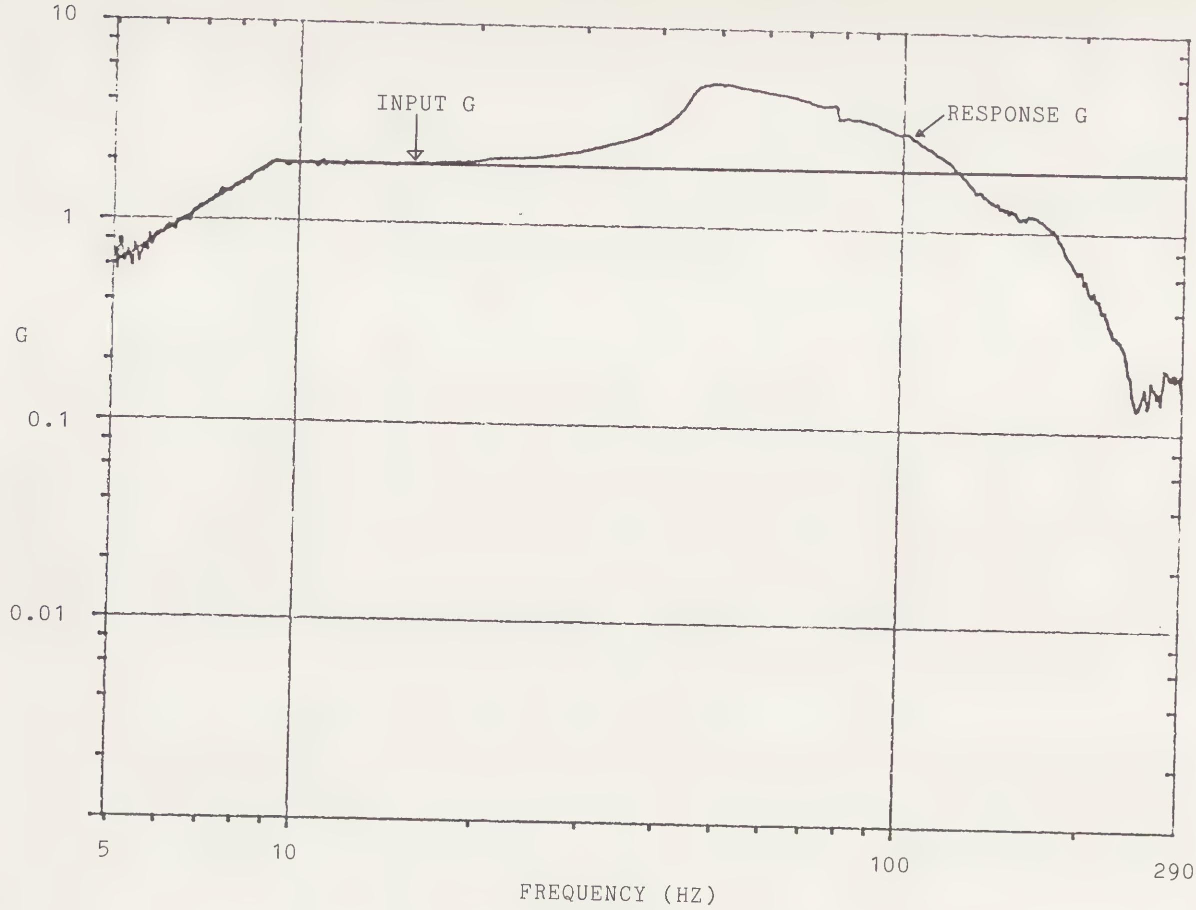


FIGURE 5B RESPONSE CURVE FOR CROSS-AXIS VIBRATION MEASURED BY ACCELEROMETER IN CENTRE OF CANVAS IN STYLE 1 CASE STANDING VERTICALLY WITH VIBRATIONAL INPUT THROUGH STANDING EDGE

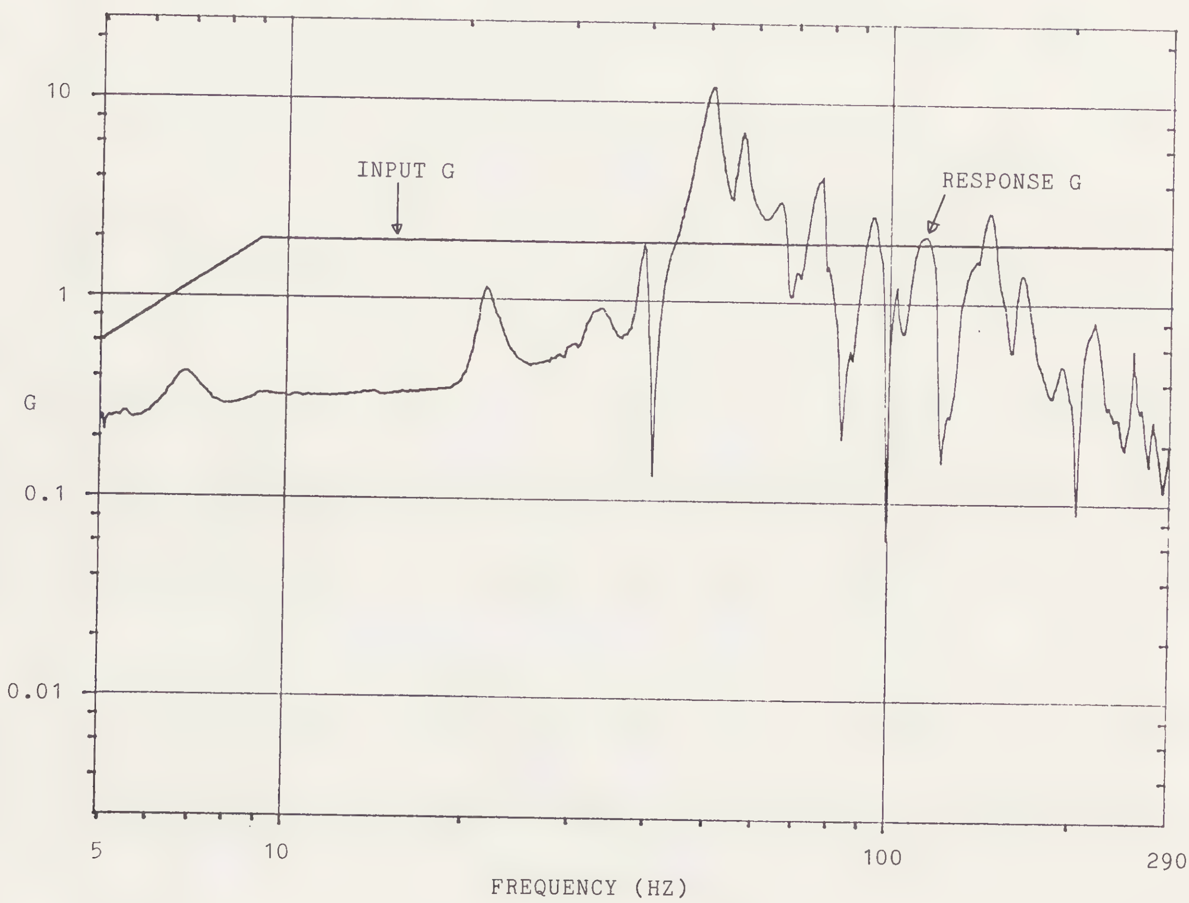


TABLE 4 RESULTS OF VIBRATIONAL RESONANCE SEARCHES

		CORNER FRAME		CENTRE FRAME		CANVAS	
		FREQUENCY (HZ)	FACTOR	FREQUENCY (HZ)	FACTOR	FREQUENCY (HZ)	FACTOR
STYLE 1 VERTICAL	VIBRATIONAL INPUT THRO STANDING EDGE	46	2.5	48	2.5	50	5.5
	VIBRATIONAL INPUT THRO SHORT SIDE	45	2.5	48	2.5	-	-
STYLE 1 HORIZONTAL	VIBRATIONAL INPUT THRO STANDING EDGE	26	3	26	3	47	4.5
	VIBRATIONAL INPUT THRO SHORT SIDE	-	-	-	-	-	-
STYLE 2 HORIZONTAL	VIBRATIONAL INPUT THRO STANDING EDGE	18	2	17	2	50	2.5
	VIBRATIONAL INPUT THRO SHORT SIDE	22	1.5	22	2	-	-

3.5 Impact Test

An impact test was used to determine the relative strengths of phenolic-coated and double-faced-aluminium plywood. The test was devised to simulate the impact of a fork-lift truck tine on test samples that measured 750 x 750mm square. A fork-lift tine weighing approximately 35 kgs was suspended from a height of 4m above the base of the test samples. Impact position was about 200mm above the lower edge of the test sample. The tine was pulled straight back to a measured vertical height above its equilibrium position and allowed to free-fall to impact. The tine was raised and impacted in a succession of equal increments until the board was considered to be in an unserviceable condition. For the phenolic-coated plywood this was when both external veneers were split and for the double-faced-aluminium plywood when it was punctured.

The maximum recorded vertical drop heights above equilibrium position were as follows:

Phenolic-coated plywood	365mm
Double-faced-aluminium plywood	930mm

This indicates that the DFA plywood is approximately two and a half times more resistant to impact than phenolic-coated plywood.

It was not possible to test the cases' response to changes in pressure. These occur during air travel when the pressure may drop to 75% of the ground level value. We may speculate (since we do not know how airtight the cases are) that while the airplane is gaining altitude, air will be drawn out of the cases in order to equalise pressures and on landing air will be forced into the cases. If the contents of the cases are cold and the air drawn in is warm and damp then there may be problems with condensation. As a precaution it should be specified that the cases are only carried in heated parts of the aircraft. Recordings made using RH and temperature solid-state memory recorders inside packing cases during flights show no unusual changes in RH on either landing or take-off (11).

The small amount of water entering the Style 1 case during the waterspray test could be prevented if the Style 1 case were made with a lift-off lid with the same seal as the Style 2 case. There would be the added advantage of doing away with the webbing restrainers which occasionally get caught in the seal of the case.

4 Conclusion

The results of the environmental tests showed that the thermal insulation of the cases is surprisingly poor. Other foam materials do not have significantly better (ie. lower) thermal conductivity. Table 5 shows thermal conductivities for various materials. The thermal insulation of the cases could be improved by using thicker layers of foam. But, since the changes in RH recorded during the tests did not give cause for conern in spite of the very low and very high temperatures, the improvement in thermal insulation is not a priority.

TABLE 5 THERMAL CONDUCTIVITIES (W/m^oC)

Still air	0.025
Expanded polystyrene	0.026 - 0.040
Polyurethane foams	0.015 - 0.035
Polyethylene foams	0.040 - 0.055
'Plastazote'	0.046
'Ethafoam'	0.046
Wood	0.085 - 0.125

There are many points to be considered on the shock protection system in the case. We have to decide if the paintings should be packed in a way that they experience less than a chosen G value for a certain drop height. It would help, not only in understanding the effects of shock on paintings but also the effects of vibration, if we could relate these G values to deterioration. The shock protection system could be improved by using thicker cushions of the polyethylene foam. It is doubtful that other foams could improve on the cushioning power of polyethylene without using an even thicker cushion, since the cushioning ability of polyethylene foam is very good, even after repeated impacts. Perhaps we should attempt to calculate the correct loading for the foam, particularly for the cushioning in the lid and base.

The results of the vibration tests show that there are no problems with the frames resonating at vibrational frequencies encountered during transport. However, the canvas does undergo quite dramatic vibrations and the frequencies of resonances are not predictable since they will depend on many factors including the size of the canvas, its weight and how tightly it is stretched. Without restraining canvases in some way it is inevitable that they will vibrate during transport and these results emphasise the importance of not allowing paintings to travel when there is any doubt about their structural stability.

The impact tests show that double-faced aluminium plywood is a stronger material than phenolic-coated plywood. The Style 2 cases are usually made in double-faced-aluminium plywood since they are often handled by fork-lift trucks and are more susceptible to rough handling. The cases are heavier but as with the increased size of case necessary to contain extra cushioning material there is a pay-off against performance.

The satisfactory design of packing cases for paintings involves optimising features such as small size, lightness, ease of handling and expense with good protection for the contents. Let us hope that the results of these tests may help us and others in achieving these aims.

5 Acknowledgements

The staff of Dristyle Products and E.P.S. (Research and Development) Ltd. have given much help in all stages of the preparation of this paper, and in particular I would like to thank David Fellowes who has been most closely associated with the work.

Garry Thomson made the initial contact with E.P.S. and set this project in motion. I would like to thank him for his advice in devising the test procedures and interpreting the results.

6 Notes and References

1. Stolow, N., Care of Works of Art in Transit and on Exhibition: Review and Assessment. Preprints of ICOM Committee for Conservation, 6th triennial meeting, Ottawa, 1981, 81/12/1.

Stolow, N., Conservation Standards for Works of Art in Transit and on Exhibition. UNESCO, Paris, Museums and Monuments Series, XVII, 1979.

2. Toishi, K., Jet Transport of Art Objects. In Museum Climatology ed. G. Thomson, IIC London conference, 1967, p 41-44.

3. Gordon, J.B., Packing of Michelangelo's 'Pietà'. Studies in Conservation, 12 (1967) 57-69.

4. The cases are designed and manufactured to National Gallery specifications by Dristyle Products Ltd., Sittingbourne.

5. The derivation of these standard sizes will be described in an article to be published in the National Gallery Technical Bulletin, 8, (1984).

6. 'Plastazote' is manufactured in the UK by BXL Plastics Ltd. The density of the 'Plastazote' is 40-50 kg/m^3 and its code number is PO 56 (Black). 'Ethafoam' is a similar closed-cell polyethylene foam manufactured by Dow Chemicals in the USA.

7. The tests were carried out by EPS (Research and Development) Ltd., Sittingbourne, with the exception of the vibration tests which were carried out at Marconi Avionics Ltd.

8. For a description of these recorders see UKIC Conservation News No. 22 November 1983 p 11-12.

9. Thomson, G., Relative Humidity Variations with Temperature in a Case Containing Wood. Studies in Conservation, 9 (1964) 153-169.

10. Stolow, N., Standards for the Care of Works of Art in Transit, in Museum Climatology ed. G. Thomson, IIC London conference 1967 p 271-284.

In this article the following formula is given:

$$\triangle RH = \frac{0.063\ W \triangle T}{0.18\ W + 0.6\ W_S}$$

W is the weight of wood and W_S the weight of silica gel in a case in which the amount of moisture-absorbent material is large relative to the amount of air in the case.

If there is no silica gel in the case then:

$$\triangle RH = 0.35 \triangle T$$

If there is the same weight of silica gel as wood then:

$$\triangle RH = 0.0808 \triangle T$$

Since the frame and other materials associated with a painting are mostly wood it would be necessary to use the same weight of silica gel as the painting to reduce the RH change to about a quarter of the value if there were no silica gel present. Lesser amounts would reduce the RH change to a lesser extent.

11. Examples of recordings made during journeys will be published in the National Gallery Technical Bulletin, 8, (1984).

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